THE USE
OF THE
GLOBES.

CATECHISM OF ASTRONOMY,

AND

The Use of the Globes,

CONTAINING

648 QUESTIONS ON THE TERRESTRIAL AND CELESTIAL GLOBES,

WITH NUMEROUS PROBLEMS FOR SOLUTION BY PUPILS.

BY

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LONDON:

RELFE & FLETCHER, CLOAK LANE,

NEAR THE MANSION HOUSE.

1845.

TO THOSE OF HIS PUPILS

WHO HAVE DISTINGUISHED THEMSELVES

BY THEIR LOVE OF KNOWLEDGE, AND THEIR PERSEVERANCE

IN ACQUIRING IT,

AND ESPECIALLY, ON THAT ACCOUNT,

TO FRANCES MATILDA BRASHER,

AND

GEORGE VERNON MARSH,

This little Work,

WRITTEN FOR THEIR INSTRUCTION,

IS, WITH A SINCERE WISH FOR THEIR GROWTH IN

KNOWLEDGE, VIRTUE, AND PIETY,

AFFECTIONATELY DEDICATED

BY THEIR TEACHER AND FRIEND,

THE AUTHOR.

CONTENTS.

PREFACE.

Many teachers may perhaps have found that the elementary books on the "Use of the Globes," at present in use, are not sufficiently explanatory. Such has been the Author's experience; it has always appeared to him that they presuppose, on the part of the pupil, a fund of knowledge seldom possessed. Thus, he has frequently met with young persons who could solve, by the globe, numerous problems, but who had no knowledge whatever of the *causes* of those phenomena which the problems were intended to illustrate. These considerations induced him to compose, for the use of his own pupils, a Catechism on Astronomy and the Use of the Globes, of which the first two parts are now submitted to teachers, and two other parts will be published as soon as

the Author's leisure will permit him to make some alteration in the arrangement of the questions. His object has been to combine with every problem sufficient scientific information to make the subject clear; but not so much as to perplex the non-mathematical student. It will be perceived that many problems usually solved by the terrestrial globe are, according to his system of instruction, solved by the celestial: he has made this change because the latter appears to him to be the clearer mode of illustration. In the First Part, some few problems are given, of which the explanations are not subjoined. These problems are repeated in the Second Part, with explanations which would not have been understood by the pupil at an earlier stage of his progress.

CATECHISM

OF

ASTRONOMY, &c.

INTRODUCTION.

As many young persons who have a slight acquaintance with geography, and can, with little difficulty, find countries and cities on maps, nevertheless feel themselves at a loss when required to point out the same places on the globe, it is advisable that a pupil, before commencing the following Catechism, should acquire a facility in finding some of the principal oceans, seas, continents, islands, capes, cities, &c. Let the pupil learn also to name and point out the principal circles on the globe. It is not necessary at present to learn any definition of them, but simply their names and situations.

The following order may be observed :—

Two-thirds of the earth's surface are water, and one-third is land.

Pacific Ocean.	Baltic Sea.
Atlantic Ocean,	Mediterranean Sea.
Northern Ocean.	Red Sea.
Southern Ocean.	Black Sea.
Indian Ocean.	Arabian Sea.
German Ocean.	Caspian Sea.

Europe, Asia, Africa, North America, South America, Australasia, Polynesia, the West Indies, the East Indies.

COUNTRIES.

Russia, Great Britain, France, Germany, Italy, Spain, Portugal, Greece, Turkey, Persia, Arabia, Egypt, Hindostan, Malaya, China, &c.

CITIES.

St. Petersburg, London, Paris, Vienna, Rome, Madrid, Lisbon, Athens, Constantinople, Teheran, Mecca, Alexandria, Calcutta, Madras, Bombay, Pekin, Canton, Nankin, Quebec, New Orleans, Pernambuco, Rio Janeiro, Buenos Ayres, Quito, Lima.

ISLANDS.

Great Britain, Ireland, Iceland, Sicily, Sardinia, Corsica, Cyprus, Cuba, Haiti, Jamaica, Ceylon, the Japan Isles, the Philippine Isles, Borneo, Sumatra, Java, Madagascar.

CAPES.

The North Cape .	the north point of Norway.
The Skaw	the north point of Denmark.
Cape Matapan . .	the south point of Greece.
Cape Clear	the south point of Ireland.
Cape St. Vincent.	the south point of Portugal.
Cape Comorin . .	the south point of Hindostan.
Cape Romania . .	the south point of Malaya.
East Cape	the north-east point of Asia.
The Cape of Good Hope	nearly the south point of Africa.

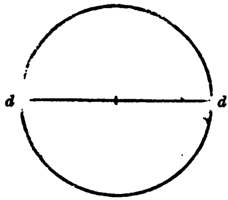
Cape Bon	the north point of Africa.
Cape Verd	the west point of Africa.
Cape Guardafui .	the east point of Africa.
Cape Raselgat . .	the east point of Arabia.
Cape Horn	the south point of South America.
Cape Sable	the south point of Florida.
Cape Blanco . . .	the west point of South America.
Cape St. Roque .	the east point of South America.

The Poles, the Axis, the Wooden Horizon, the Brass Meridian, the Quadrant of Altitude, the Dial or Hour Circle, the Equator, the Ecliptic, the two Tropics, the two Polar Circles, the Parallels of Latitude, the Meridians, the five Zones and their boundaries.

PART THE FIRST,

CONTAINING

240 QUESTIONS ON THE TERRESTRIAL GLOBE.



1. WHAT is a circle? The space contained by one curved line, which is such that every point of it is at the same distance from a certain point, within the figure, called the centre. But *with respect to the globe*, the term "circle" is frequently applied to the curved line itself, instead of to the space within it.

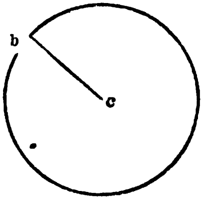
2. What is the proper name of the curved line? It is called *the circumference* of the circle.

3. What is the derivation of the word "circumference?" Latin, *fero*, I bear or carry; and *circum*, around or about.

4. What is meant by the "diameter" of a circle? A straight line drawn through the centre, and terminated each way by the circumference, *d d*.

5. What is the derivation of the word diameter? Greek, *dia*, through; and *metron*, a measure.

6. What is the radius of a circle? A line drawn from the centre to the circumference, *c b*.

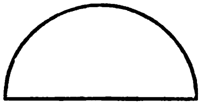


7. What is the derivation of the word "radius?" It is the Latin for "a ray."

8. Is the same line called by any other name? Yes; a semi-diameter.

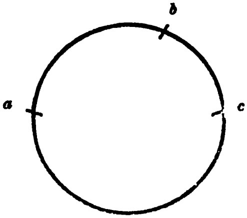
9. What is the derivation of "semi?" It is the Latin for "half."

10. What is half a circle called? A semicircle.



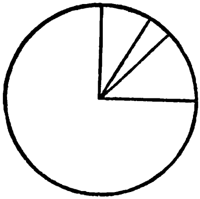
11. What is half a circumference called? A semicircumference.

12. What is an arc? Any portion of a circumference is called an arc; as *a b*, *b c*.



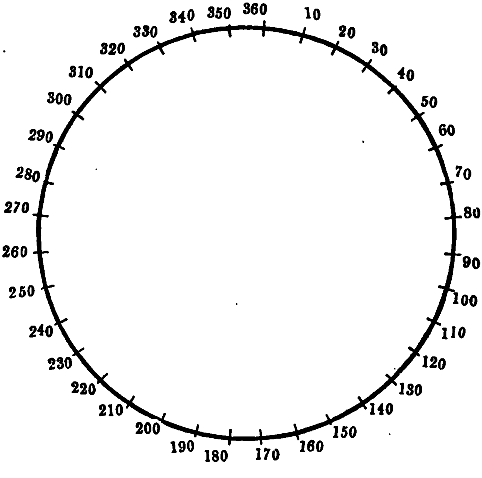
13. What is a quadrant, a sextant, an octant? A quadrant is the fourth part of a circumference; a sextant the sixth part; and an octant the eighth part.

14. What is the derivation of these words? *Quadrans*, the Latin for a fourth part; *sextans*, for a sixth part; and *octans*, for an eighth part.



15. In the annexed figure, point out the arc that is a quadrant, the arc that is a sextant, and the arc that is an octant.

16. What is a degree? The 360th part of the circumference of a circle.



17. How many degrees are there in a semicircumference, in a quadrant, in a sextant, and in an octant? 180 in a semicircumference, 90 in a quadrant, 60 in a sextant, 45 in an octant.

18. Find by the brass meridian of the globe at how many degrees distance each pole is from the equator.—90 degrees.

19. Find how many degrees the poles are from each other.—180 degrees.

20. Find how far each tropic is from the equator.—23½ degrees.

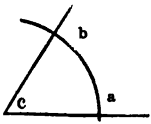
21. Find how far each polar circle is from the equator.—66½ degrees.

22. Find how far each polar circle is from the pole.—23½ degrees.

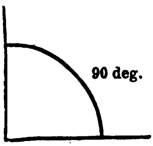
23. What is an angle? The opening between two lines meeting in a point.

24. What is the derivation of the word angle? Latin, *angulus*, a corner.

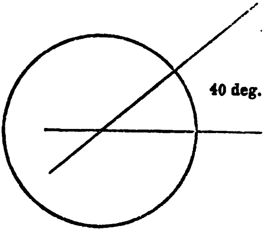
25. How is the *size* of an angle estimated? An angle is measured by the arc intercepted between its sides, the angular point being made the centre of a circle. Thus the angle *c* is measured by the arc *a b*, and is said to be an angle of as many degrees as there are in that arc. If the arc *a b* contains 60 degrees, then the angle *c* is an angle of 60 degrees.



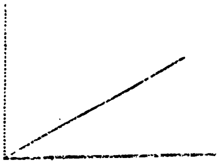
26. What is a right angle? An angle of 90 degrees; *i.e.* it is measured by a quadrant. Its sides are upright to each other.



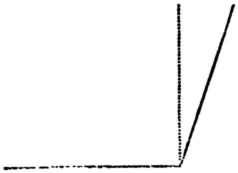
27. What is meant by saying



that one line crosses another at an angle of 40 degrees? That if the angular point be taken as a centre, and a circle be described, the arc, intercepted by the two lines, will contain 40 degrees.

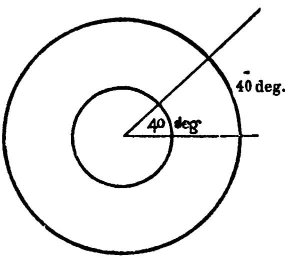


28. What is an acute angle? One that is smaller than a right angle, or one of fewer than 90 degrees.



29. What is an obtuse angle? One that is greater than a right angle, or one of more than 90 degrees.

30. Does the size of an angle depend at all upon the length of its sides? No.



31. Why not? Because, whether the circle described for the purpose of measuring it be a large one or a small one, the arc between the sides will still contain the same number of degrees.

32. If two circles be described from the

angular point, will not the arc of the outer circle be greater than that of the inner one? It will.

33. Then will it not contain a greater number of degrees? No; each circumference contains 360 degrees, therefore the degrees of the outer one are *larger* than those of the inner one; but the arc of the outer one does not contain a *greater* number of degrees than that of the inner one; it contains the *same* number of *larger* degrees.

34. Prove this.—The arc of the outer circumference is the same *part* of that circumference as the arc of the inner circumference is of the inner circumference. In the figure above, each arc is the ninth part of the whole circumference of which it forms a part; and each arc, therefore, contains the ninth part of 360 degrees, viz. 40 degrees.

35. What is the complement of an angle? Its deficiency from a right angle; *i.e.* the difference between its degrees and 90°. The complement of an angle of 57 degrees is 33 degrees.

36. Tell the complements of the following angles:—

An angle of 43. An angle of $66\frac{1}{2}$.
An angle of $19\frac{1}{4}$. An angle of $35\frac{3}{4}$.

37. Are the various circles on the artificial globe to be found on the surface of the earth itself? No; they are merely imaginary.

38. Of what use are they? They are used for solving various geographical problems.

39. What is the difference between a great circle and a small one? A great circle divides

the globe into two *equal* parts; and a small circle divides it into two *unequal* parts.

40. What are the two principal great circles on the globe? The equator and the ecliptic.

41. Where is the equator? Midway between the Poles.

42. What is it used for? Finding the longitude.

43. What is that circle called the equinoctial? A circle in the heavens precisely over the equator on the earth.

44. Where is the ecliptic? A circle crossing the equinoctial in two points, called equinoctial points.

45. Is it a circle on the earth or in the heavens? In the heavens.

46. If it is a circle in the heavens, what is that circle, called the ecliptic, which is drawn on the terrestrial globe? A circle supposed to be described on the earth precisely under the true ecliptic in the heavens. It bears the same relation to the equator that the true ecliptic does to the equinoctial.

47. At what angle does the ecliptic cross the equinoctial? At an angle of 23½ degrees.

48. What does the ecliptic represent? The apparent annual course of the sun in the heavens.

49. Why do you call the sun's course in the heavens *apparent?* Because the sun does not really travel round the earth, but only *appears* to do so, in consequence of the earth's motion round him.

50. Has the earth any other motion besides

travelling round the sun? Yes, several; but the principal one is its diurnal motion.

51. What is that? Revolving upon its axis once in every twenty-four hours.

52. What is caused by the annual motion of the earth? It causes the difference of seasons.

53. What is caused by the diurnal motion of the earth? The succession of light and darkness.

54. How so? The earth, by turning on its axis from west to east, makes the sun appear to travel daily round it from east to west: that half of the earth which is, at any time, turned towards the sun being enlightened, and the half which is turned from it being in darkness.

55. How is the situation of a place upon the earth determined? By its latitude and longitude.

56. What do you mean by the latitude of a place? Its distance from the equator, north or south.*

57. What do you mean by the longitude of a place? The distance of its meridian from the *first* meridian, east or west.†

58. What do you mean by the meridian of a place? A circle drawn through it from the north pole to the south pole, cutting the equator at right angles.

59. What do you mean by the first meridian? Any meridian fixed upon for the purpose of measuring the longitude from.

* An arc of its meridian, contained between the place and the equator.

† An arc of its parallel of latitude, contained between its meridian and the first meridian.

60. Have all nations fixed upon the same meridian for this purpose? No.

61. What meridian is used by the English nation as a first meridian? The meridian passing through Greenwich; a place near London.

62. What is the greatest latitude a place can have? 90 degrees; but only the two poles can have this latitude.

63. What is the greatest longitude a place can have? 180 degrees.

64. Why cannot a place have a greater longitude than 180 degrees? Because a place which is *more* than 180 degrees to the east of the *first* meridian, is necessarily *fewer* than 180 degrees to the west of it.

65. How is the latitude of a place to be found by the globe? Bring the place to the brass meridian, and observe the number of degrees which it is from the equator, north or south.

66. How is the longitude of a place to be found by the globe? Bring the place to the brass meridian, and observe what degree of the equator is then under it. If the numbers on the equator are increasing to the right hand, the longitude is east; and if they are increasing to the left hand, the longitude is west.

EXAMPLES.—Find the latitude and longitude of the following places:—Madras, Pekin, Bombay, Canton, New Orleans, Rio Janeiro, Lisbon, Rome, Constantinople.

67. If the latitude and the longitude of a place given, how may that place be found by the globe? Find the given degree of longitude on

the equator, and bring it to the brass meridian; then, under the given degree of latitude on the brass meridian, the required place will be found.

68. What is a degree? The 360th part of the circumference of a circle.

69. Are all degrees of the same size? No.

70. Why not? The circumference of a small circle is *less* than that of a large circle, and consequently its 360th part is less.

71. At what part of the earth are degrees of longitude the greatest? On the equator. They decrease as the latitude increases.

72. Do you mean that a degree of longitude is smaller in a high latitude than in a low latitude? Yes.

73. Why? Because the parallels of latitude are smaller the nearer they are to the poles, and therefore their 360th parts are smaller; or, because the meridians approach each other as they approach the poles; and since there are always the same number of degrees between any two of them, the degrees themselves must be smaller.

74. What do you mean by parallels of latitude? Small circles parallel to the equator.

75. What do you mean by a circle's being parallel to the equator? Drawn so that every part of it is at the *same distance* from the equator.

76. Are all *degrees of latitude* of the same size? Yes.

77. Why? Latitude is reckoned on a meridian, and all the meridians are *great* circles of the globe; consequently they are all of the same size.

78. You have defined a degree to be the 360th part of the circumference of a circle—what is a minute? The 60th part of a degree.

79. What is a second? The 60th part of a minute.

80. How are degrees, minutes, and seconds, marked? A degree, thus °; a minute, thus ′; a second, thus ″.

81. Read the following: 79° 11′ 24″.—Seventy-nine degrees, eleven minutes, and twenty-four seconds.

82. What is a minute of time? The 60th part of an hour.

83. What is a second of time? The 60th part of a minute of time.

84. In what period of time does the earth revolve upon its axis? In 24 hours.

85. How many degrees of longitude pass under the sun in 24 hours? 360.

86. How many in one hour? The 24th part of 360; viz. 15.

87. What is the earth's rate of revolution? It turns through 15° in one hour of time; and therefore through 15′ in one minute of time, and through 15″ in one second of time.

88. Does not the sun appear to travel daily round the earth from east to west? Yes.

89. What is the cause of that appearance? It is occasioned by the daily rotation of the earth on its axis from west to east.

90. What is the sun's apparent rate of motion? He appears to move in a circle, and to pass through 15° of that circle in one hour of time, through 15′ of it in one minute of time, and through 15″ of it in one second of time.

91. Give an illustration of this rate of motion.—If the sun is observed at 9 o'clock in the morning to be in any particular point of the heavens, he will be found 15° to the west of that point at 10 o'clock, and 30° to the west of it at 11 o'clock.

92. What is meant by the term noon? Apparent noon, at any place, is that period of the day which is precisely midway between sunrise and sunset.

93. When is it noon at any place? In common language, when the sun, in his daily course, comes exactly over the meridian of that place; but properly when the meridian of that place is brought by the earth's rotation precisely under the sun.

94. Which of two places, the more easterly or the more westerly, has noon first? The more easterly.

95. Why? Because the earth's rotation, being from west to east, brings the more easterly under the sun first.

96. Then, which of two places has the later hour of the day? The more easterly.

97. Why? Because it has noon first.

98. Is it ever noon at two places precisely at the same instant? Yes, all places on the same meridian have noon at the same instant.

99. Why? Because they all come under the sun at the same instant.

100. Do all places, then, in the same longitude have the same hour of the day? They do. When it is 5 o'clock (or any other hour) at any given place, it is 5 o'clock also at *every* other

place in the same longitude, and at *no* place that is *not* in the same longitude.

101. Then on what does the difference of time between any two places depend? On the difference of their longitude.

102. What must be the difference of longitude between two places which differ in time by one hour? 15 degrees.

103. Why? Because the earth turns through 15° in one hour.

104. What is the difference of longitude between two places which differ in time by three hours? Three times 15°; viz. 45 degrees.

105. What is the difference of time between two places that differ in longitude by 60°? The 15th part of 60°; *i.e.* 4 hours.

106. When it is 11 o'clock A.M. at any place, what is the time at another place 45° to the east of it? Three hours *later;* i.e. 2 o'clock P.M.

107. Why later? Because the more *easterly* place has the *later* hour of the day.

108. When it is 11 o'clock A.M. at any place, what is the time at another place 45° to the west of it? Three hours earlier; *i.e.* 8 o'clock A.M.

109. Why earlier? Because the more *westerly* of two places has the *earlier* hour of the day.

110. If the earth is one hour in turning through 15° (as you said), how long is it in turning through 1°? The 15th part of an hour; *i.e.* 4 minutes.

111. What is the difference of time between two places which differ in longitude by 1°? Four minutes.

112. What is the difference of time between

two places which differ in longitude by 5°? Five times 4 minutes; *i. e.* 20 minutes.

113. What is the difference of longitude between two places which differ in time by 36 minutes? The fourth part of 36°; *i.e.* 9°.

114. How do you find, by the globe, the difference of longitude between two places? First find the longitude of each place; then, if both the longitudes are east, or both west, the less must be subtracted from the greater for their difference. But, if one longitude is east, and the other west, they must be added for their difference. If their sum, however, should exceed 180°, it must be subtracted from 360°, to find their difference.

EXAMPLES.—Find the difference of longitude between Madeira and Constantinople; Rome and Rio Janeiro; Alexandria and Bombay; Madras and Pekin; Lima and Teheran; Pernambuco and Calcutta.

115. What is the rule for finding the difference of time between any two places? Find their difference of longitude. If it be less than 15°, multiply by 4, and the product is the difference of time *in minutes*. If it exceed 15°, divide by 15, and the quotient is the difference of time *in hours*. Should any remainder occur in the division, multiply it by 4, and the product is the number of *minutes* corresponding to those remaining degrees.

116. Two places differ in longitude by 112°, what is their difference of time?

$$\begin{array}{r} 15\overline{)112}(7 \text{ hours.} \\ 105 \\ \hline 7 \\ 4 \\ \hline 28 \text{ minutes.} \end{array}$$

7 hours and 28 minutes.

EXAMPLES.—Find the difference of time between the places given as examples to Question 114.

117. If the time at one place be given to find the time at another, must the difference of time be added or subtracted? If the place of which the time is given be the more *westerly*, the difference must be *added*, because the more *easterly* place has the *later* time; but if the place, the time of which is given, be the more *easterly*, the difference must be subtracted, because the more *westerly* place has the earlier time.

EXAMPLES.—When it is noon at Madeira, what is the time at Mexico?

When it is noon at Mexico, what is the time at Madeira?

When it is 5 A.M. at Alexandria, what is the time at Madras?

When it is 5 A.M. at Madras, what is the time at Alexandria?

When it is 7 P.M. at Rio Janeiro, what is the time at Bombay?

When it is 7 P.M. at Bombay, what is the time at Rio Janeiro?

When it is 7 hours 35 minutes A.M. at Lima, what is the time at Teheran ?

When it is 7 hours 35 minutes A.M. at Teheran, what is the time at Lima ?

118. Cannot the difference of time be found by the globe ? Yes, imperfectly.

119. Explain the manner of doing so.—Bring one of the given places to the brass meridian, and set the hour circle to 12 o'clock ; turn the globe eastward, or westward, as required, until the other given place comes to the brass meridian ; the time passed over by the dial will show the difference of time between the places.

Examples the same as those to Question 114.

120. If the time at one place be given, can the time at another be also found by the globe ? Yes, in the following manner :—Bring the place at which the time is known to the brass meridian, and set the dial to the given time. Turn the globe eastward or westward (as required) until the other place comes to the brass meridian ; the dial will then show the time at that place.

Examples the same as those to Question 117.

121. If the difference of time between two places be given, how can their difference of longitude be found therefrom ? Reduce the time to minutes, and divide by 4, the quotient gives degrees of longitude.

122. The difference of time between two places is 4 hours and 35 minutes ; what is their difference of longitude ?

4 hours 35 minutes.
60

4)275

$68\frac{3}{4}°$ difference of longitude.

EXAMPLES.—What is the difference of longitude between places which have the following differences of time?—

Difference of time, 4 hrs. 13 min.
" " 7 hrs. 43 min.
" " 8 hrs. 17 min.
" " 9 hrs. 49 min.
" " 10 hrs. 27 min.

At a place in longitude 17° E., it is $3\frac{1}{2}$ A.M., what is the longitude of that place where it is then $11\frac{1}{4}$ A.M.?

At a place in longitude 47° W. it is $11\frac{1}{2}$ A.M., what is the longitude of that place where it is then $4\frac{1}{4}$ P.M.?

At a place in longitude 112° W. it is $9\frac{3}{4}$ A.M., what is the longitude of a place at which it then is $6\frac{1}{4}$ A.M.?

At a place in 71° E. longitude, it is $3\frac{1}{2}$ P.M., what is the longitude of that place where it is then $7\frac{1}{4}$ A.M.?

123. You said that the earth revolves daily at the uniform rate of 15° an hour: are all places on it carried round with the same velocity in consequence of this motion? No; those places nearest to the equator are carried round the fastest.

124. How so, since all places are carried through 15° in an hour? They are all carried through 15° in an hour, but the degrees are *larger* near to the equator than they are near to the poles; consequently, places near to the equator are carried through a *greater space* than those near to the poles; and therefore, since the time is the same (one hour), they must of course be carried faster.

125. What is a geographical mile? The 60th part of an equatorial degree; *i.e.* an equatorial minute.

126. Is a geographical mile a variable quantity, like a degree of longitude, which decreases as the latitude increases? No; a geographical mile is always the same.

127. A degree of longitude, you say, varies, and a geographical mile is always the same; do *all* degrees of longitude contain the same number of geographical miles? No; some contain more than others.

128. Explain.—The greater the latitude of a place, the *smaller* the degree of longitude is at that place; and, consequently, the fewer miles it contains.

129. How many miles an hour are those places, situated on the equator, carried by the earth's rotation? Fifteen degrees, each degree being 60 miles; *i.e.* 15 times 60—900 miles.

130. Are any other places carried as quickly as that? No.

131. Is there any method of finding how many miles are contained in a degree of longitude in *every* degree of latitude? Yes, an accurate table

has been calculated by Trigonometry; but there is an imperfect method of doing so by the globe.

132. Explain that method.—Lay the quadrant of altitude on the globe, along the given latitude, and parallel to the equator; observe how many degrees of the quadrant are intercepted between any two meridians. If the meridians pass through every 15th degree of the equator, multiply by 4; but if the meridians pass through every 10th degree, multiply by 6. The product in either case will be the number of geographical miles contained in a degree of longitude in the given latitude.

EXAMPLES.—How many geographical miles are contained in a degree of longitude at the following places:—New Orleans, New York, Madeira, Vienna, London, St. Petersburgh, North Cape?

133. How do you find at what rate per hour any place is carried from west to east by the earth's rotation? Find how many geographical miles are contained in a degree of longitude at that place, and multiply by 15.

EXAMPLES.—Find at what rate the places named in the preceding question are carried.

134. What is the length of a degree of longitude at the poles? Nothing; in fact the poles have no longitude; all the meridians *there* meet in a point of the first meridian.

135. Are there any other places which have no longitude? Yes, all places on the first meridian.

136. Are there any places which have no latitude? Yes; all places on the equator

137. Is there any part of the globe which has neither latitude nor longitude? Yes; that point in which the first meridian crosses the equator.

138. How do you find the difference of latitude between two places? Find the latitude of each place. If they are both on the same side of the equator, subtract the less from the greater; if the places are on opposite sides of the equator, add their latitudes.

EXAMPLES.—Find the difference of latitude between Alexandria and Rome; Cape Horn and the Cape of Good Hope; Rio Janeiro and Lisbon; Madeira and St. Helena.

139. How do you find the direct distance between two places? Place the quadrant of altitude on the globe *so* that it passes through both the places, and observe the number of degrees between them. Multiply this number by 60 to find their distance in geographical miles, and by 69.1 to find it in English miles.

EXAMPLES.—Find the distance between those places named as examples to the preceding question.

140. Which is the greater, a geographical mile, or an English mile? A geographical mile.

141. How do you know that? An equatorial degree contains only 60 geographical miles, but it contains 69.1 English miles.

142. You have spoken of the earth's rotation on its axis: what is the meaning of the word

axis? It is the Latin for an axle, or pole on which a wheel turns.

143. What is the earth's axis? An imaginary line supposed to pass through its centre, on which it makes its daily rotation like a wheel on the axle of a coach.

144. What are the poles of the earth? The extremities of its axis.

145. What are the poles of the heavens? Points in the heavens precisely over the poles of the earth. The north pole is within one degree of a bright star, thence called the pole-star.

146. What is meant by the horizon of a place? There are two horizons, the sensible and the rational.

147. What is the sensible horizon of a place? It is generally defined to be the boundary line of our sight, at that place, or the curved line in which the heavens and the earth appear to meet each other.

148. You say it is *generally* so defined; is there then a *better* definition? Yes; it is better to consider the sensible horizon of a place, as a plane touching the earth at that place, and extended in every direction to meet the heavens.

149. What do you mean by a plane? A flat surface.

150. What is the rational *horizon* of a place? A plane supposed to pass through the centre of the earth parallel to the sensible horizon of that place, and extended in every direction to meet the heavens.

151. Are there any places on the earth so situated that the earth's axis is perpendicular

(*i. e.* at right angles) to their horizons? Yes, the two poles, and those only.

152. Are there any places so situated that the earth's axis makes *no* angle with their horizons? Yes; all places on the equator. The earth's axis coincides with their *rational* horizon, and is therefore parallel to their *sensible* horizon.

153. What angle does the earth's axis make with the horizon of any other place? An angle of as many degrees as are equal to the latitude of the place.

154. Cannot the wooden horizon be made to represent the rational horizon of *any* place? Yes.

155. How? By elevating the pole as many degrees above the wooden horizon as are equal to the latitude of the place; and thereby causing the earth's axis to make the required angle with it.

156. What is this operation called? Rectifying the globe to the latitude of a place.

157. Place the poles in the horizon.—For what place is the globe now rectified? For all places on the equator.

158. Why? Such places have *no* latitude; the earth's axis makes *no* angle with the horizon, but coincides with it.

159. What is this position of the sphere called? A right sphere.

160. Why? Because all the parallels of latitude cut the horizon at right angles.

161. What inhabitants of the earth live in a right sphere? Those who live at the equator.

162. Elevate the north pole 90° above the

horizon.—For what place is the globe now rectified? For the north pole.

163. Why? The latitude of the north pole is 90° north, and the *north* pole is now elevated 90°.

164. Elevate the south pole 90° above the horizon.—For what place is the globe now rectified? For the south pole, and for a similar reason.

165. What are these two positions of the sphere called? Each of them is called a parallel sphere.

166. Why? Because in such a position the parallels of latitude are parallel to the horizon.

167. What inhabitants of the earth live in a parallel sphere? Those who live at the poles, if there are any.

168. Elevate the north pole 40° above the north point of the horizon.—For what places is the globe now rectified? For all places in 40° north latitude.

169. When the pole is elevated to any number of degrees less than 90, what is such a position of the globe called? An oblique sphere.

170. Why? Because, when the globe is in such a position, all the parallels of latitude cut the horizon obliquely.

171. What inhabitants of the earth live in an oblique sphere? All, except those at the equator and at the poles.

172. Does not the length of the day (considered as the period of light) vary at the same place? Yes.

173. When do the longest day and the shortest

night occur at all places in north latitude (except those in the frigid zone)? When the sun is in the tropic of Cancer.

174. When do the shortest day and longest night occur? When the sun is in the tropic of Capricorn.

175. When do the longest day and the shortest night occur to places in south latitude (except those in the frigid zone)? When the sun is in the tropic of Capricorn.

176. When do the shortest day and longest night occur? When the sun is in the tropic of Cancer.

177. On what day of the year is the sun in the tropic of Cancer? On the 21st of June.

178. What are the seasons at that time? Summer to the inhabitants of north latitude, and winter to those of south.

179. When is the sun in the tropic of Capricorn? On the 21st of December.

180. What are the seasons at that time? Summer to the inhabitants of south latitude, and winter to those of north.

181. On what days of the year is the sun in the equinoctial points? On March the 21st, and September 23d.

182. What are the seasons when the sun is in the equinoctial point on March 21st? Spring to places in north latitude, and autumn to those in south latitude.

183. What are the seasons when the sun is in the equinoctial point on September 23d? Autumn to places in north latitude, and spring to those in south.

184. How is the ecliptic divided? Into 12 equal portions, called signs of the zodiac, each sign containing 30°. Six of these signs are to the north of the equinoctial, and six to the south of it.

185. Name the six northern signs.—Aries, the Ram; Taurus, the Bull; Gemini, the Twins; Cancer, the Crab; Leo, the Lion; Virgo, the Virgin.

186. Name the six southern signs.—Libra, the Balance; Scorpio, the Scorpion; Sagittarius, the Archer; Capricornus, the Goat; Aquarius, the Water-bearer; Pisces, the Fishes.

187. Which of these are the equinoctial points? The first degree of Aries, and the first degree of Libra.

188. Which are called the solstitial points? The first degree of Cancer, and the first degree of Capricorn.

189. On what days is the sun in the equinoctial points, or equinoxes? On the 21st of March, and the 23d of September.

190. On what days is the sun in the solstitial points, or solstices? On the 21st of June, and the 21st of December.

191. What is meant by the sun's longitude? His place in the ecliptic reckoned in signs and degrees, from the first degree of Aries, *eastward* through the whole ecliptic.

192. What is meant by the sun's declination? His distance from the equinoctial, north or south.

193. What is the greatest declination the sun can have? 23½ degrees.

194. Why? Because the ecliptic crosses the equinoctial at an angle of 23½ degrees.

195. What is the sun's longitude when he has his greatest declination? His greatest northern declination is on June 21st, when he is in the tropic of Cancer; and then his longitude is 3 signs. His greatest southern declination is on December 21st, when he is in the tropic of Capricorn, and then his longitude is 9 signs.

196. How is the sun's longitude, on any given day, to be found? By examination of the wooden horizon, where there are two adjacent circles, one containing divisions for the months and days, and the other the corresponding signs and degrees of the ecliptic. Thus, on the 20th of August, the sun is found to be in the 27th degree of Leo; therefore his longitude on that day is 4 signs and 27 degrees.

EXAMPLES. — Find the sun's longitude on April 3d, June 1st, August 19th, October 11th, December 3d, and February 2d.

197. How do you find the sun's declination on any given day? Find his place in the ecliptic (as in the preceding case), bring that place to the brass meridian, and observe the degree which is above it. Thus, bringing the 27th of Leo to the brass meridian, I find the degree above it to be 13½ north; therefore the sun's declination on August the 20th is 13½° north.

EXAMPLES.—Find the sun's declination on the days given as examples to the preceding question.

198. Considering day as the period from sunrise to sunset, how can you find its length, on any day of the year, at a place which is not in

the frigid zones? Thus :—Rectify the globe for the latitude of the place, which causes the wooden horizon to represent the rational horizon of that place upon the supposition that the place is at rest in the centre of the sphere. Find the sun's place in the ecliptic on the given day, and bring it to the eastern edge of the horizon. Set the dial to 12, and then turn the globe westward until the sun's place is thereby brought to the western edge. The number of hours passed over on the dial shows the length of the day.

EXAMPLES.—What is the length of the day at the following places on the given days?—

At Madeira, on March 1st.

At Rio Janeiro, on June 3d.

At Bombay, on May 7th.

At Pekin, on September 25th.

At Constantinople, on October 5th.

At Barbadoes, on November 7th.

At Quebec, on August 9th.

At Canton, on February 2d.

At Paris, St. Petersburgh, and Madeira, on the longest day in north latitude.

At Cape of Good Hope, Cape Horn, and Buenos Ayres, on the longest day in south latitude.

199. How can you find the length of the night? By finding the length of the day and subtracting it from 24 hours.

EXAMPLES.—Find the length of the night at the places in the preceding problem.

200. How can you find the time of sunrise

and sunset? Bring the sun's place to the brass meridian, and set the dial to 12. Turn the globe eastward until the sun's place comes to the horizon, and observe the hours passed over by the dial. So many hours *before* noon is the time of sunrise, and the same number *after* noon, the time of sunset.

EXAMPLES.—Find the time of sunrise and sunset in the preceding examples.

201. Cannot the length of the day and of the night be determined from the time of sunrise or sunset? Yes, because double the time of sunrise is the length of the previous night, and double the time of sunset the length of the previous day.

202. Give an example.—Suppose the time of sunrise on any day to be half-past 5, then the length of the night just passed was 11 hours. But half-past 5 is 6½ hours *before* noon, therefore the sun will set 6½ hours after noon, and the length of the day will be 13 hours.

203. Give an example from the time of sunset.—Suppose the sun to set on any day at half-past seven, then the length of the day was 15 hours. But when the sun set 7½ hours *after* noon, he rose 7½ hours *before* noon, or at half-past 4; consequently, the length of the preceding night had been 9 hours.

EXAMPLES.—When the sun rises at the following times, what has been the length of the night, and what will be the length of the day? 5 o'clock, ¼ to 6 o'clock, ¼ past 4 o'clock, ½ past 7 o'clock, ¼ to 5 o'clock.

When the sun sets at the following times, what has been the length of the preceding day and night? ¼ to 7 o'clock, ½ past 5 o'clock, 10 minutes to 8 o'clock, 14 minutes past 6 o'clock, 17 minutes past 5 o'clock.

204. When the pole is elevated to the latitude of a place, what does the wooden horizon represent? The rational horizon of that place.

205. When the globe is thus elevated for the purpose of showing the alternations of light and darkness at any place, how are those alternations supposed to be produced? By the diurnal journey of the sun round the earth from east to west.

206. Is this supposition correct? No; the alternations of light and darkness are really caused by the diurnal rotation of the earth upon its axis from west to east, while the sun remains nearly stationary.

207. Does the false supposition lead to any error? No; because the effects are the same as if the sun *did* journey round the earth as he *appears* to do.

208. You say that the alternations of light and darkness are really caused by the rotation of the earth on its axis—can the globe be so placed as to illustrate these as they really happen on any given day? Yes; the pole must be elevated to the sun's declination on that day.

209. Does the wooden horizon then represent the rational horizon of any place? No; it represents the boundary of light and darkness on that day: that is, it may be made to separate the enlightened half of the earth from the unenlight-

ened, and thus present the appearance of the earth, with respect to the sun, at any given hour.

210. What is the sun's declination on that day of the year which is the longest to all places in north latitude? 23½ degrees north.

211. Elevate the north pole 23½ degrees.—Now where is the sun supposed to be? The sun is stationary in that point of the heavens which is precisely over 23½ degrees north on the brass meridian. Consequently, when any place is brought to the brass meridian (*i. e.* under the sun) the globe represents the precise appearance of the earth with respect to the sun when it is noon at that place.

212. Bring London to the brass meridian.—What does the globe represent now? The wooden horizon now separates that half of the earth which, being turned towards the sun, is enlightened, from that half which, being turned away from the sun, is in darkness, at the moment when it is noon at London on the 21st of June. In this manner the wooden horizon, by elevating the pole to the sun's declination, is made to represent the boundary of light and darkness.

213. What appearances does the sun present to those places, which, in this position of the globe, are situated along the western edge of the boundary of light and darkness? The earth revolves from west to east; consequently these places are just emerging from darkness into light, and the sun appears to be rising in the *eastern* edge of their *horizon*.

214. What appearance does the sun present to those places which, in this position of the

globe, are situated along the eastern edge of the boundary of light and darkness? They are just passing from light to darkness, and the sun appears to be setting in the *western* edge of their *horizon.*

215. What appearance does the sun present to those places which are under the brass meridian? To each place he appears on the meridian.

216. You say that the earth revolves from west to east: turn the globe in that direction until the dial has passed over three hours—what does the globe represent now? It represents the appearance of the earth with respect to the sun when it is 3 o'clock in the afternoon at London, on June 21st. The wooden horizon is now the boundary of light and darkness *at that hour.*

217. How do you find the length of any given day in this manner? Elevate the pole to the sun's declination on that day, and the wooden horizon represents the boundary of light and darkness. Bring the given place to its western edge, turn the globe *eastward* until the place is thereby brought to its eastern edge, and observe the number of hours passed over on the dial.

EXAMPLES.—Find the length of the day and of the night at those places which are given as examples to Question 198.

218. What is the derivation of the term *amphiscii?* It is derived from two Greek words; viz. *amphi*, on both sides, and *skia*, a shadow.

219. How is it applied? The inhabitants of the torrid zone are called *amphiscii.*

220. Why? Because their shadows *at noon* fall sometimes to the north, and sometimes to the south, according to the sun's declination.

221. When is the shadow of an inhabitant of the torrid zone directed due north at noon? During all that portion of the year when the sun at noon appears due *south* of him.

222. When does this occur? If the place is in *south* latitude, it occurs on all those days of the year when the sun's declination *south* is greater than the latitude; but if the place is in north latitude it occurs on all those days when the sun's declination is *south*, and also on those days when the sun's declination is *north*, but *less* than the latitude.

223. When is the shadow of an inhabitant of the torrid zone directed due *south* at noon? During all that portion of the year when the sun at noon appears due north of him.

224. When does this occur? If the place is in north latitude, in occurs on all those days when the sun's declination *north* is greater than the latitude; but, if the place is in south latitude, it occurs on all those days when the sun's declination is north, and also on those days when the sun's declination is *south*, but *less* than the latitude.

225. What is the derivation of the term *ascii?* *Skia*, a shadow, and *a*, without.

226. How is it applied? On those days when the sun is in the zenith of a place at noon, the inhabitants of that place then have no shadow, and therefore they are called, with reference to those days, *ascii*.

227. What is the derivation of the term *heteroscii?* *Skia*, a shadow, and *h-eteros*, another, different.

228. How is it applied? The inhabitants of the temperate zones are called *heteroscii*, because their shadows, at noon, always point in opposite directions; those of the north temperate zone having their shadows pointing due *north*, and those of the south temperate zone having their shadows pointing due south.

229. What is the reason that the inhabitants of the north temperate zone always have their shadows pointing towards the north? Because the sun is always to the *south* of that zone.

230. What is the reason that the inhabitants of the south temperate zone always have their shadows pointing towards the south? Because the sun is always to the north of that zone.

231. What is the derivation of the term *periscii?* *Skia*, a shadow, and *peri*, around.

232. How is it applied? The inhabitants of the frigid zones are called *periscii*, because at those times of the year when the sun does not set to a place for twenty-four hours, its inhabitants have their shadows, in that time, directed to every point of the compass.

233. What is the derivation of the term *antœci?* Greek *anti*, opposite to, and *oikeo*, I dwell.

234. How is it applied? The inhabitants of places which are on the same meridian, and in equal, but opposite latitudes, are called the *antœci* of each other.

235. What is the derivation of the term *periœci?* *Peri*, around, and *oikes*, I dwell.

236. How is it applied? The inhabitants of places situated on the *same* parallel of latitude, but in opposite longitudes (*i. e.* on meridians which are 180° apart) are called the periœci of each other.

237. What is the derivation of the term *antipodes?* Greek *anti*, opposite, *podes*, the feet.

238. How is it applied? The inhabitants of places situated in equal but opposite latitudes, and on opposite meridians, are called the antipodes of each other.

239. Why? Because they have their feet opposite to each other—*i. e.* at the extremities of a diameter of the globe.

240. How can we find those places of which the inhabitants are the antœci, the periœci, or the antipodes of the inhabitants of a given place? Bring the given place to the brass meridian, and observe the latitude; then, the inhabitants of that place which is under the same degree in the opposite hemisphere are the antœci. Turn the globe half round (*i. e.* from 12 to 12 by the dial); then the inhabitants of that place which is under the same degree in the same hemisphere are the periœci; and those of the corresponding place in the opposite hemisphere are the antipodes.

Examples.—Find the antœci, the periœci, and the antipodes of the inhabitants of Lisbon, of Rome, of Constantinople, of Rio Janeiro, of Cape Horn, of Cape of Good Hope.

PART THE SECOND,

CONTAINING

408 QUESTIONS ON THE HEAVENS AND THE CELESTIAL GLOBE.

Note.—The Pupil will comprehend many of the definitions and problems of this Second Part much more easily by being shown an Armillary Sphere. It should be explained to him that the various circles of that sphere are the *edges* of the intersecting planes mentioned in Chapter the Second. In the Author's opinion, an Armillary Sphere is so necessary, that one should always be near the Celestial Globe on which the Pupil is working his problems.

QUESTIONS

ON

THE CELESTIAL GLOBE.

CHAPTER I.

First Observations.

1. WHAT appearance do the heavens present to a spectator on the earth?

On whatever part of the earth the spectator is situated, they appear to him like a vast concave vault, of which his situation forms the centre.

2. How is this vault limited?

By a plane extending from the spectator to the heavens, and which itself appears circular.

3. What is this plane called?

The observer's *sensible* horizon.

4. What is meant by the *rational* horizon of an observer?

A plane passing through the earth's centre in a direction parallel to his sensible horizon.

5. What is the derivation of the term horizon?

Greek *h-orizo*, I limit.

6. Do not the heavens appear to *surround* the earth like a hollow sphere?

Yes, a sphere of which the earth's centre may be considered as the centre.

7. Then this heavenly sphere is divided into two portions by an observer's sensible horizon, and also by his rational horizon; is it not?

It is.

8. What is the difference between these portions?

Those into which it is divided by his sensible horizon are *unequal*, the portion above being smaller (though by very little) than the portion below. Those into which it is divided by his rational horizon are *equal*, each being exactly half of the whole heavenly sphere.

9. How do these two horizons *limit* the observer's view?

His *sensible* horizon separates that portion of the heavens which, at any given point of time, he *can* see, from that which, at the same point of time, he can *not* see. His *rational* horizon separates that portion which, at any given point of time, he *would be able* to see, from that which he would *not*, provided his view could embrace half the heavenly sphere.

10. What bodies do we perceive in the heavenly sphere?

The first which attracts attention, by its size and splendour, is the *sun;* next the *moon;* and then the stars.

11. Is there not a difference with respect to the *times* at which we see these bodies?

Yes; we can see the sun by day only; we can see the moon by night and by day: but we cannot, in general, see the stars by our unassisted vision, except by night.

12. What is the reason that we can see the sun by *day* only?

Because the term "day" (when used in opposition to night) signifies that period of time during which the sun is visible.

13. What is the reason that we cannot see the stars by day?

Many stars are above the horizon by day; but we cannot see them, because the comparatively faint light which they shed is lost in the superior brilliancy of the sun.

14. Are all these heavenly bodies situated in the concave *surface* of the heavenly sphere?

In reality they are not, for they are at very different distances from us; but they appear to us to be so situated.

15. Why?

Because their distances are so very great, that the differences of those distances are not appreciable by our vision; consequently they appear to us as if they were all at the *same* distance; and for this reason, the heavens are considered as a sphere, and all these bodies supposed to be situated in its concave surface.

16. Are these bodies at rest?

They appear to be in motion.

17. Give an example.

The sun appears to rise (or become visible)

in one part of the horizon, to travel through the heavenly vault within our view, and then to set (or disappear) in another part of the horizon.

18. Is this apparent motion confined to the sun?

No; the moon appears to do the same.

19. Do not the stars appear to do so likewise?

Some of them appear to rise and set like the sun and moon; but others appear to revolve in circles without going below the horizon.

20. Is there any heavenly body which does not appear to move?

No; they all, without exception, appear to move.

21. Do the heavenly bodies appear to change their situations with respect to each other, in consequence of this motion?

The stars do not.

22. What inference do we draw from this fact?

That the stars *themselves* do not move; but that the whole heavenly sphere in which they are situated revolves upon its axis.

23. What do you mean by the *axis* of the heavenly sphere?

An imaginary line passing through its centre, on which it appears to revolve.

24. Is not the centre of the earth the centre of the heavenly sphere?

It is.

25. Then the axis of the heavenly sphere

passes through the centre of the earth, does it not?

It does, and a portion of it forms the axis of the earth.

26. What are the north and south points, or poles of the heavens?

The extremities of their axis.

27. What is meant by the *meridian* of an observer?

A plane passing through him and the axis of the heavens from north to south.

28. In what kind of line does such a plane meet the heavens?

Because the heavens appear spherical, it meets them in the circumference of a circle; and the term meridian is sometimes applied to this circumference also.

29. In what manner are the terms north and south referred to the observer's horizon?

The plane called the meridian must pass at right angles through the plane called the horizon; consequently the circular edge of the former crosses the circular edge of the latter in two points; these two points are called the north and south points of the horizon.

30. How is the horizon divided by this passing of a meridian through it?

Its plane being a circle, is divided into semicircles; and its edge being the circumference of a circle, is divided into semi-circumferences.

31. What names are given to these two semicircumferences?

That one at which the heavenly bodies appear to rise is called the *eastern* edge of the horizon; and that where they appear to set is called the *western* edge of the horizon.

32. Where are the east and west *points* of the horizon?

The east is that point of the eastern edge which divides it into two equal arcs, and consequently is a quadrant, or 90° distant from the north and south points. The west is that point of the western edge which divides it in a similar manner.

33. Show the north, south, east and west points of the horizon.

34. Into how many portions is the whole edge of the horizon divided by these four points?

Into four, each being a quadrant, and therefore containing 90°.

35. Are these portions subdivided?

Yes; each quadrant is divided into two equal arcs by points called—

The north-east. The south-east.
The north-west. The south-west.

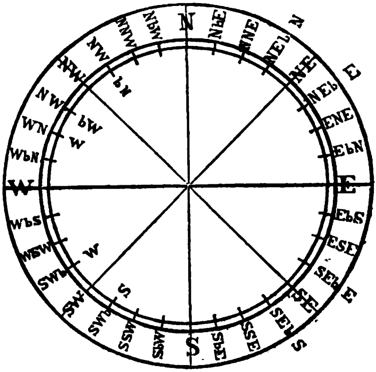
Each of these arcs is consequently an octant, and contains 45°.

36. Show those points on the wooden horizon.

37. Is the whole edge of the horizon divided into more than eight parts?

Yes; each of these octants is subdivided into four parts; so that the whole horizon is thus divided into 32 small arcs, each arc containing $11\frac{1}{4}$ degrees. These points of division have received

different names, as in the annexed representation.



38. What is a mariner's compass?

A representation of the horizon, divided as in the preceding figure. By means of a magnetic needle, its north and south points are kept always pointing nearly to the north and south points of the horizon.

39. Does not a magnetic needle point *due* north and south?

No; it is subject to a variation.

40. What is the variation at present in England?

It points rather more than 24½ degrees to the *west* of the north point of the horizon, and consequently the same distance to the *east* of the south point of the horizon.

41. Is this variation always the same ?

No ; the variation itself varies in different latitudes and longitudes, and at the *same* place in different years.

42. You said that the stars do not change their situations *with respect to each other* in consequence of their apparent motion—is this true of all stars ?

No ; some few *do* change their situations with respect to the others, and appear to wander (as it were) amongst them.

43. What inference is drawn from that appearance ?

That such stars, besides the motion which they have in common with the whole heavenly sphere, have also distinct motions of their own.

44. What are these stars called ?

Planets ; from a Greek word which signifies *to wander.*

45. What are those stars which do not change their relative situations called ?

They are called *fixed stars.*

46. Do the sun and the moon preserve their relative situations among the stars ?

No ; their situations are continually changing.

47. What inference is drawn from that fact ?

That they also, besides the motion which they have in common with the whole heavenly sphere, have distinct motions of their own.

48. What two general inferences with respect to the motion of the heavens may be drawn from the preceding observations ?

First. That the whole heavenly sphere revolves round the earth from east to west; most of the heavenly bodies rising in the eastern edge of the horizon, gradually ascending from it until they cross the meridian, and then gradually descending from the meridian towards the horizon, until they set in the western edge of it.

Second. That the sun, the moon, and the planets, besides this motion which they have in common with the whole sphere, have also proper motions of their own, by which they change their situations *in* that sphere.

49. Is the first of these inferences true?

No; further investigation convinces us that the *apparent* motion of the heavenly sphere from east to west is caused by the actual rotation of the earth upon its axis from west to east.

50. Is the second inference true?

It is with respect to the moon and the planets; but with respect to the sun it is *not*.

51. What is a celestial globe?

A representation of the whole heavens on the convex surface of a sphere.

52. Do not the heavens present to us the appearance of a *concave* sphere?

Yes; and therefore a person, when using the artificial globe, must suppose himself to be in the centre, and looking *up* at the stars on its concave surface.

CHAPTER II.

The Equator and the Equinoctial—The Zenith and the Nadir—Positions of the Sphere—Stars which rise and set—Circumpolar Stars.

53. WHAT are the equator and the equinoctial?

Suppose a plane passing through the centre of the earth (which is also the centre of the heavenly sphere) to be extended to meet the heavens; it will intersect the convex surface of the earth in a circle, and also the concave surface of the heavens in a circle. If such a plane be supposed to pass through the centre in such a direction that every part of its circular edge is equidistant from the poles, then the circle in which it intersects the *earth* is the equator, and that in which it intersects the heavens is the equinoctial.

54. How does the equinoctial divide the heavens?

Into two equal parts, called the northern and the southern hemispheres of the heavens.

55. How does the equator divide the earth?

Into two equal parts, called the northern and the southern hemispheres of the earth.

56. At what distance is every part of the equinoctial from the poles of the heavens?

A quadrant, or 90° from each pole.

57. At what distance is every part of the equator from the poles of the earth?

A quadrant, or 90° from each.

58. When we speak of the rising of a heavenly body above the horizon, do we speak of the sensible or rational horizon of the observer?

Of the sensible horizon.

59. Then a period of time elapses between the moment at which any celestial object actually rises above the *rational* horizon of an observer, and that at which he sees it rise?

Yes; but this period of time, in consequence of the vast magnitude of the heavenly sphere as compared with the magnitude of the earth, is so small, that it needs not be taken into consideration, except in accurate astronomical calculations. Moreover, it is decreased by the combined agency of two causes, called refraction and parallax.

For the reason just given, the term horizon is used in the following pages to signify the *rational* horizon, or rather the circular edge in which it meets the heavens.

60. How are the poles of the heavens situated with respect to the horizons of observers, on different parts of the earth?

To an observer at the equator, the poles of the heavens coincide with the poles of the horizon. To an observer in north latitude, the north pole of the heavens is *above*, and the south pole below the corresponding points of the horizon. To an observer in south latitude, the south pole of the heavens is *above*, and the north pole below the corresponding points of the horizon.

61. How are the poles of the heavens situated with respect to observers at the poles of the earth?

The north pole of the heavens is precisely over the head of an observer at the north pole of the earth; and the south pole of the heavens is precisely over the head of an observer at the south pole of the earth.

62. What is that point of the heavens which is precisely over the head of an observer called?

His zenith.

63. Where is that point of the heavens which is called his nadir?

Precisely under his feet; it is the zenith of an observer situated on exactly the opposite point of the earth.

64. At what distance is the horizon of an observer from his zenith and nadir?

Exactly midway between them, every part of it being a quadrant, or 90° distant from each.

65. What is the reason that an observer at the equator has the poles of the heavens in his horizon?

The horizon of an observer (as appears from the last statement) is 90° from his zenith; but the zenith of an observer at the equator is in the equinoctial, and the equinoctial is 90° from the poles of the heavens: therefore, his horizon could not be exactly 90° from his zenith, without passing *through* the poles of the heavens.

66. What is the reason that an observer in north latitude has the *north* pole of the heavens *above* his horizon, and the *south* pole below it?

Because the zenith of an observer in north latitude must be between the equinoctial and the north pole of the heavens, and therefore *fewer* than 90° from it. Consequently, his horizon could not be 90° from his zenith without passing *below* the north pole; and if *below* the north pole, it must be *above* the south pole, or it would not divide the sphere *equally*.

67. What is the reason that an observer in south latitude has the *south* pole of the heavens *above* the horizon, and the *north* pole *below* it?

Because the zenith of an observer in south latitude must be between the equinoctial and the south pole of the heavens, and therefore fewer than 90° from it; consequently, his horizon could not be 90° from his zenith, without passing *below* the south pole, and *above* the north pole.

68. What is the reason that an observer at either of the poles of the earth has the corresponding pole of the heavens in his zenith?

Because he is situated exactly 90° from every point of the equator, his zenith must be exactly 90° from every point of the equinoctial; and the only points of the heavens so situated are the poles.

69. Does not the heavenly sphere receive different names, according as it is viewed from different parts of the earth?

Yes; the appearance it presents, as viewed from the equator, is called a right sphere; as viewed from either pole, a parallel sphere; and, as viewed from every other part of the earth, an oblique sphere.

70. What portion of the heavens is seen in a right sphere?

The whole; an observer at the equator may see the heavens from pole to pole. During one revolution of the heavenly sphere every star rises, and every star sets.

71. Place the globe in a right sphere, and show that such is the case.

Because the poles of the heavens, in a right sphere, coincide with the north and south points of the horizon, the poles of the globe must be placed in the wooden horizon, which will then represent the horizon of the equator. Now, as the globe is turned upon its axis, it may be seen that every star comes above the horizon, and that every star goes below it.

72. What portion of the heavens is seen in a parallel sphere?

The half only; an observer at the north pole would see the northern hemisphere only; and an observer at the south pole would see the southern hemisphere only. The stars neither rise nor set, but revolve round the observer in circles, of which every part is above the horizon.

73. Put the globe in a north parallel sphere, and show the truth of this statement. In a north parallel sphere, the north pole of the heavens is in the zenith, and the zenith is always 90° above the horizon. I must, therefore, elevate the north pole of the globe 90° above the wooden horizon, which will then represent the horizon of the observer. Now, as the globe is turned upon its axis, it may be seen that every star in the

northern hemisphere still remains above the horizon, and that every star in the southern hemisphere still remains below it.

74. What portion of the heavens is seen in an oblique sphere?

More than the half, but less than the whole, comes above the horizon during every rotation of the heavenly sphere.

75. Upon what does the size of this portion depend?

Upon the observer's distance from the equator, *i.e.* his latitude.

76. In what manner? The nearer he is to the equator, the greater the portion that comes above the horizon; and the farther he is from the equator, the less that portion; *i.e.* the less the latitude, the greater the visible portion of the heavens; and the greater the latitude, the less that portion.

77. In an oblique sphere, do all the stars rise and set during one revolution of the heavenly sphere?

No; some rise and set, others describe circles, without going below the observer's horizon, whilst others are not seen at all by the observer, as they describe circles without rising above his horizon.

78. What is the cause of these phenomena?

In an oblique sphere, one pole of the heavens is elevated above the observer's horizon, and the other depressed below it; consequently, those stars which are near the *elevated* pole, revolve, with the sphere, without going below the

horizon; and those near the depressed pole, without coming above it.

79. At what height above the horizon does the elevated pole appear in an oblique sphere?

As many degrees as are equal to the observer's latitude. Thus, to an observer in 40° north latitude, the north pole of the heavens appears to be 40° above the north point of the horizon, and the south pole of the heavens is depressed 40° below the south point of the horizon. To an observer in 40° south latitude, the south pole of the heavens is elevated 40° above the south point of the horizon, and the north pole depressed 40° below the north point of it.

80. Explain this elevation of the pole in proportion to an observer's latitude.

Because the equinoctial is precisely over the equator, the zenith of an observer in latitude 40° (north or south) must be 40° distant (north or south) from the equinoctial, and, therefore, 50° distant from the north or south pole of the heavens. But the horizon is 90° distant from the zenith, and therefore its north or south point must pass 40° below the north or south pole of the heavens.

81. When we elevate the north or south pole of an artificial globe as many degrees above the corresponding point of the wooden horizon as are equal to any given latitude, what is the act of doing so called?

Rectifying the globe to the given latitude, and thereby causing the wooden horizon to represent the real horizon of any place in that latitude.

82. Rectify the celestial globe to 40° north latitude, turn the globe from east to west, and observe if any stars do not go below the horizon.

Many do not.

83. Within what distance of the north pole are those stars?

Because the north point of the horizon is now 40° from the north pole of the heavens, those stars which do not go below the horizon must be within 40° of that pole.

84. At what distance are they from the equinoctial?

Because the equinoctial is 90° from either pole, those stars which are within 40° of the pole must be more than 50° from the equinoctial.

85. Are not 50° exactly the difference between the latitude for which the globe is rectified, and 90 degrees?

They are.

86. What is the difference between the latitude of any place and 90 degrees called?

The complement of its latitude, or its co-latitude.

87. Then those stars whose distance from the equinoctial exceeds the co-latitude of the place are the stars that do not go below the horizon of that place?

They are the only ones that do not.

88. What are such stars called?

Circumpolar stars.

89. What is the distance of a heavenly body from the equinoctial called?

Its declination, which, of course, is either north or south.

90. What is the declination of those stars which never set to any given place?

All those stars whose declination, *in the same direction as the latitude*, exceeds the co-latitude of a place, never set to that place; but are circumpolar.

91. Turn the globe again, and observe what stars do not *come above* the horizon.

All those within 40° of the south pole.

92. How far are they from the equinoctial?

More than 50° to the south of it.

93. What inference do you draw from this fact?

That all those stars whose declination, *in a direction contrary to the latitude*, exceeds the co-latitude of a place, never rise to that place.

94. What stars rise and set to any place with every revolution of the celestial sphere?

All those whose declination, *in either direction*, does *not* exceed the co-latitude of that place.

95. What stars never set, and what stars never rise, to London?

The latitude of London being 51½° north, its co-latitude is 38½°. All those stars in *north* declination greater than 38½° never set, and all those in *south* declination greater than 38½° never rise, to London.

96. What stars rise and set to London with every revolution of the celestial sphere?

All those whose declination, either north or south, is not greater than $38\frac{1}{2}°$.

97. Rectify the globe for London, and show the correctness of these two statements.

98. What is a circle of perpetual apparition?

An imaginary circle in the heavens, parallel to the equinoctial, and whose distance from it, *in the same direction* as the latitude, is equal to the co-latitude of a place, is a circle of perpetual apparition for that place.

99. Why is it so called?

Because all stars between it and the elevated pole are *always above* the horizon of that place.

100. What is a circle of perpetual occultation?

A circle in every respect similar, except that it is on the *contrary* side of the equinoctial.

101. Why is it so called?

Because all stars between it and the depressed pole are *always below* the horizon of that place.

102. Where are the circles of perpetual apparition and occultation for Lisbon?

The latitude of Lisbon is 39° north; therefore its co-latitude is 51°. The circle of perpetual apparition is therefore 51° *north* of the equinoctial, and that of perpetual occultation is 51° south of the equinoctial.

103. Into what three great classes may the heavenly bodies be divided with respect to any place on the earth?

Into those that never go below the horizon, those that never come above it, and those that rise and set every 24 hours.

CHAPTER III.

Grouping of the Stars into Constellations, and method of classifying them.

104. WHAT is a constellation?

An assemblage of stars, circumscribed by the outline of some assumed figure, as a ram, a bear, &c.

105. Are all the stars considered as being thus collected into groups?

All the fixed stars are.

106. Why are the stars thus grouped?

In order that any person may be easily directed to that part of the heavens in which any particular star is situated.

107. Have these groups of stars any resemblance to the figures whose names they bear?

A very slight one, if any; and perhaps a better arrangement of them into groups might easily be effected; but as the present one, owing to its antiquity, has come to be universally adopted, a change in this respect is not deemed to be advisable.

108. How are the stars of each constellation arranged and designated?

They are arranged in the order of their apparent brightness, and designated by the letters of

the Greek alphabet—the earlier letters being applied to the brightest stars, and the later letters to the less bright of the same constellations.

109. Give an example, and show the stars on the globe.

In the constellation called Orion, the brightest star is designated by α, the 1st letter; the next in brilliancy by β, the 2d letter; the next in brilliancy by γ, the 3d letter; the next in brilliancy by δ, the 4th letter; and in like manner with them all.

110. Suppose there are more stars in a constellation than there are letters in the Greek alphabet?

Then other alphabets are used, upon the same principle, to distinguish other stars of less importance.

111. What alphabets?

Generally the small *Italic* and the large Roman alphabets; and if these do not embrace all the stars, then those of the least importance are designated by numbers.

112. Repeat the Greek alphabet, and make the characters.

α Alpha	β Beta	γ Gamma
δ Delta	ϵ Epsilon	ζ Zeta
η Eta	θ Theta	ι Iota
κ Kappa	λ Lambda	μ Mu
ν Nu	ξ Xi	o Omicron
π Pi	ρ Rho	σ ς Sigma
τ Tau	υ Upsilon	φ Phi
χ Chi	ψ Psi	ω Omega.

113. Have not some of the stars received names?

A few have; for instance,

α in Orion is called Betelgeuse,

β in Orion is called Rigel;

and γ in Orion is called Bellatrix.

114. Is there not a vague classification of the stars according to what is called their different magnitudes?

Yes, because the brightest stars appear to the eye to be the largest.

115. How many classes called magnitudes are there?

As many as ten or twelve; but stars of the first five magnitudes only are discernible by the naked eye.

116. How are these magnitudes marked on a celestial globe?

By the number of points with which each star is depicted. On most globes, stars of the first magnitude have 8 points, those of the second 7, those of the third 6, those of the fourth 5, and those of the fifth 4.

117. Name and point out the principal constellations and stars in the northern hemisphere of the heavens.

Aries:

$\left.\begin{array}{l}\alpha \text{ (of the 2d mag.)} \\ \beta \text{ (of the 3d mag.)}\end{array}\right\}$ both in the head.

Taurus:

α, or Aldebaran (of the 1st mag.) in the face.

β (of the 2d mag.) at the end of a horn.

γ (of the 3d mag.)
δ (one of a small cluster) } in the face.
ε (of the 3d mag.)

Gemini:

α, or Castor (1st mag.) } in the head and
β, or Pollux (2d mag.) } neck.
γ (2d mag.) near the feet.

Cancer:

α, or Acabene, (4th mag.) in one of the claws.

Leo:

α, Regulus, or Cor Leonis, (1st mag.) in the breast.
β, or Deneb, (1st mag.) in the tail.
γ (2d mag.) in the mane.
δ (2d mag.) near the tail.
ε (3d mag.) in the head.

Virgo: (part of this constellation is in the southern hemisphere.)

α, or Spica Virginis, (1st mag.) in the hand.
β (3d mag.) in the head.
γ (3d mag.) } in the
δ (3d mag.) } girdle.
ε, or Vendemiatrix, (3d mag.) in the arm.

Böotes:

α, or Arcturus, (1st mag.) between the knees.
β (3d mag.) in the face.
γ (3d mag.) } in the shoulders.
δ (3d mag.) }

Hercules:

α, (3d mag.) in the forehead.
β, (3d mag.) in the shoulder.

Aquila and Antinöus:

α, or Altair, (1st mag.) in the neck of the eagle.

β (3d mag.) in the forehead of Antinöus.

Cygnus:

α, (2d mag.) in the back.

Pegasus:

α, or Markeb, (2d mag.) in the wing.

β (2d mag) in the thigh.

Andromeda:

α, (2d mag.) in the head.

β, (2d mag.) in the girdle.

Caput Medusæ, and Perseus:

α, or Algeneb, (2d mag.) in the back of Perseus.

β, or Algot, (2d mag.) in the head of Medusa.

Auriga:

α, or Capella, (1st mag.) on the back.

β (2d mag,) in the shoulder.

Ursa Major:

α, or Dubbe,	(1st mag.)	in the back.
β	(2d mag.)	
γ	(2d mag.)	
δ	(2d mag.)	
ε	(2d mag.)	in the tail.
ζ	(2d mag.)	
η	(2d mag.)	

Note.—These seven stars are vulgarly called Charles's wain. α and β are called the pointers, because a line drawn through them points almost directly to the north pole of the heavens.

Cepheus:
α, (3d mag.) in the shoulder.
β, (3d mag.) in the girdle.
Cassiopeia:
α, or Schedar, (3d mag.) in the breast.
β (3d mag,) under the arm.
Ursa Minor: the pole star is at the extremity of the tail.

118. Name and point out a few of the principal constellations and stars in the southern hemisphere of the heavens.

Libra:
α and β, each of the 2d mag.
Scorpio:
α or Cor Scorpionis (1st mag.) near the centre.
β (2d mag.) near one of the claws.
Sagittarius:
α and β, both of the 4th mag., and both in one of the legs.
Capricornus:
α and β, both of the 3d mag., and both in the head.
Aquarius:
α, β, γ, of the 3d mag., and in the arms.
δ, or Scheat, of the third mag., in the leg.
Pisces, (part of this constellation is in the northern hemisphere):
α and β, both of the 3d mag.; α is in the bend of the string which connects the fishes, and β in the mouth of the southernmost fish.

Cetus:

α, or Menkar, (2d mag.) in the jaw.

β (3d mag.) in the tail.

Orion, (part of this constellation is in the northern hemisphere):

α, or Belegeuse, (1st mag.) in the shoulder.

β, or Rigel, (1st mag.) in the heel.

γ, or Bellatrix, (2d mag.) in the shoulder.

δ, ϵ, ζ, all of the 2d mag., and all in the girdle.

Canis Major:

α, or Sirius, called also the Dog-star, (1st mag.) in the snout.

β, (2d mag.) in a paw.

Canis Minor (in the northern hemisphere):

α, or Procyon, (1st mag.)

Hydra:

α, or Cor Hydræ, (1st mag.) near the middle.

Centaurus:

α, (1st mag.) in one of the hoofs.

Eridánus:

α, or Acherner, (1st mag.) in the southern extremity.

Piscis Australis:

α, or Fomalhaut, (1st mag.) in the mouth.

Phœnix.

Grus.

Pavo.

Indus.

CHAPTER IV.

The apparent motion of the Sun.

119. You have already stated that the sun appears to have a motion of his own, distinct from that which he has from east to west in common with the whole heavenly sphere—in what direction is this motion?

During one portion of the year he appears to be moving northward in the heavens, and during another portion of the year he appears to be moving southward.

120. How has this been ascertained?

By observing the sun's height above the horizon as he crosses the meridian on different days of the year.

121. Explain.

Suppose the observations to be made in north latitude, and consequently that the *north* pole is the one elevated above the observer's horizon. By observing the sun's height above the south point of the horizon, as he crosses the meridian, it is found to be less on the 21st of December than on any other day of the year, the greatest on the 21st of June, and, during the interval, greater on each succeeding day than it was on the preceding one; therefore we conclude that, from the 21st of December to the 21st June, the

sun has been gradually moving *northward* in the heavens.

122. This proves the sun's apparent motion *northward;* but how is it known that he appears to move *southward* also?

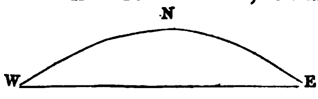
After the 21st of June he crosses the meridian at points successively lower, until, on the 21st of December he again crosses it at his least elevation.

123. Is this apparent motion of the sun exactly north and south; that is, does it coincide in direction with a meridian?

No; he appears also to move in the heavens from west to east.

124. Can his motion be of such a kind as to carry him forward from west to east, whilst he is *at the same time* approaching the north or south?

Certainly; a body may travel towards two points at the same time; for instance, if a body travel along the curved line from W to E, it will at the same time, through one portion of its course, be approaching N, and through another portion of its course be receding from N. Such is the motion of the sun in the heavens.



125. How has this apparent motion of the sun from west to east been ascertained?

By comparing the times of the sun's setting on different days with those of some known star.

126. Explain.

It must be remembered that though we do not see the stars by day on account of the sun's superior brilliancy, many of them are nevertheless above the horizon at the same time that he is; consequently, shortly after the sun has set, we see stars appear in different parts of the heavens, whose rising we did not see, because they rose whilst the sun was above the horizon.

127. Proceed.

Now, suppose we watch the sun setting on any particular evening, and, shortly after he has set, perceive a star in the western part of the heavens. Suppose this star is watched until it sets, and the period of time between the setting of the sun and that of the star is found to be one hour; the sun *on that* evening sets one hour before the star;—this is our first observation.

128. What is the next?

If the setting of the sun and of the same star be observed again after the interval of a few days, it will be found that the sun sets *less* than an hour before the star; and this fact convinces us that the sun has changed his place and moved *eastward* in the heavens since our first observation.

129. How so?

The setting of both bodies is caused by the equable rotation of the whole heavenly sphere upon its axis from east to west; therefore one of the two bodies must have changed its place in the sphere or an hour would still elapse between their respective settings. But we know that the stars do *not* change their places; therefore the sun must have approached the star; to do which

he must have moved *eastward*, because the body which sets last must be to the *east* of that which sets first.

130. Is this conclusion confirmed by subsequent observations?

Yes; the space of time between the setting of the sun and that of the star gradually diminishes, until at length they set *together*, and afterwards the star sets first, so that we no longer see it in the evening. This gradual diminution of the time is occasioned by the gradual approach of the sun to the east. When the sun is just as much to the east as the star, they set at the same instant. When the sun is more to the east than the star, the star sets first.

131. Is this conclusion with respect to the sun's apparent motion from west to east confirmed by observations made on the times of his rising as well as his setting?

Yes; suppose the sun is observed on any morning to rise shortly after a star; after the lapse of a few days it will be found that he rises at a *greater* interval after the star, and when a few more days have elapsed, that he rises at a *still greater* interval after the star. This increase of time between their respective risings confirms the notion that the sun has increased his distance from the star by moving *eastward* in the heavens.

132. From your description of the sun's apparent motion northward and southward, it appears that, at the expiration of a year he is restored to the same height on the meridian as he

had at first;—does his motion from west to east also restore him to the same relative situation, with respect to a star, as he had at first?

Yes; at the expiration of a year he will be found again to set one hour before the star on which our first observation was made.

133. What inference is to be drawn from this fact?

Since this motion is always in the *same direction*, the sun cannot be restored by it to his original place in the heavens, otherwise than by having described a complete circle in them.

134. Combining these two apparent motions of the sun, what conclusion do we come to with respect to his annual course?

That he describes in a year a complete circle in the heavens; one-half of that circle being in the northern hemisphere, and the other half in the southern hemisphere.

135. What is the Ecliptic?

The circle thus apparently described in the heavens by the sun, in the course of a year.

136. If one-half of that circle is in the northern hemisphere and the other in the southern, it must cross the equinoctial in two points—does it so?

It does; and those two points are called the equinoctial points.

137. Does the sun really move in the heavens in the manner we are led to suppose from the preceding observations?

No; further investigation of the subject proves

that he is stationary, or very nearly so, and that these appearances are caused by the *actual* motion of the *earth* round the sun.

138. How is the ecliptic divided?

Into 12 equal parts, called signs of the zodiac, each part containing 30 degrees. Six of these signs are, of course, to the north of the equinoctial and six to the south.

139. What is the zodiac?

A portion of the heavens extending about 8 degrees on each side of the ecliptic.

140. What is the derivation of the word zodiac?

Greek *zodion*, an animal.

141. Why is the term applied to this space in the heavens?

Because most of its divisions take their names from those of animals.

142. Name the northern signs?

Aries, Taurus, Gemini, Cancer, Leo, Virgo.

143. Name the southern signs?

Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.

144. Can you illustrate by the globe the gradual motion of the sun northward and southward, by showing his meridian altitudes on December 21st, March 21st, June 21st, and September 23d, as they appear at London?

Yes; I first make the wooden horizon represent the horizon of London, by elevating the north pole $51\frac{1}{2}°$ above its north point. On the 21st of December the sun is in the 1st

degree of Capricorn; bringing that point of the ecliptic to the eastern edge of the horizon, I find that the sun on that day rises considerably to the south of the east point; and by turning the globe from east to west, I see that he crosses the meridian at an altitude of only 15 degrees, and having described a very small arc, sets considerably to the south of the west point.

On the 21st of March the sun is in the 1st degree of Aries, one of the equinoctial points. Turning the globe as before, I find that the sun, on that day, rises *in* the east point, crosses the meridian at an altitude of 38½ degrees, and, having described a much larger arc than before, sets *in* the west point.

On the 21st of June, the sun is in the 1st degree of Cancer. Turning the globe as before, I find that the sun rises considerably to the *north* of the east point, crosses the meridian at an altitude of 62 degrees, and having described a very large arc, sets considerably to the north of the west point.

On the 23d of September the sun is again in the equinoctial, (the 1st degree of Libra,) and we have exactly the same appearances as on the 21st of March.

145. What are the tropics?

Two circles in the heavens parallel to the equinoctial, and 23½ degrees distant from it. The northern one passes through the 1st degree of Cancer, and is the boundary of the sun's progress *northward*. The southern tropic passes through the 1st degree of Capricorn, and is the boundary of the sun's progress *southward.*

146. Show the tropics on the globe.

147. What is the derivation of the word "tropic"?

Greek *trepo*, I turn.

148. Why is the term applied to these circles?

Because the sun, as soon as he has reached either of them, appears to turn (as it were) and pursue his course in a contrary direction.

149. As the sun never goes beyond the tropics, what is the greatest declination he can have?

Twenty-three and a half degrees.

150. What name is given to the 1st degree of Cancer and the 1st degree of Capricorn?

They are called the solstices.

151. What is the derivation of the term "solstice"?

Latin *sol*, the sun, and *sto*, I stand still.

152. Why is the term applied to these two points?

Because a little before and after the sun is in these points, he varies in declination so slowly, that he appears to be nearly stationary, or to stand still.

153. On what days is the sun in the equinoctial points?

On the 21st of March and the 23d of September.

154. On what days is the sun in the solstices?

On the 21st of June and the 21st of December.

155. Can you, by the globe, illustrate the manner in which we acquire our knowledge of the sun's apparent motion in the ecliptic from west to east?

Yes; at London, on the 14th of May, the sun may be observed to set one hour before the star α (or Betelgeuse) in Orion. To place the globe in such a position that it shall accurately represent the appearance of the heavens as viewed from London at that time, I must first elevate the pole to the latitude, then bring the star to the western edge of the horizon, and (since the sun sets one hour *before* the star) turn the globe backwards from west to east one hour by the dial. That portion of the globe now above the horizon, represents the appearance of the heavens as viewed from London at sunset on May 14th, and that degree of the ecliptic which is now in the western edge of the horizon was the sun's place on that day; that degree is the 23d of Taurus. This is our first observation.

156. Proceed to another.

On the 29th of May the sun and Betelgeuse set to London at the same instant. I must therefore bring the star to the western edge of the horizon and observe what degree of the ecliptic is then in the same edge:—that degree is the 7th of Gemini; consequently, in the interval from the 14th to the 29th of May, the sun has moved *eastward* in the ecliptic from the 23d

degree of Taurus to the 7th degree of Gemini—14 degrees. This is our second observation.

157. Proceed to a third.

On the 11th of June the sun sets to London one hour *after* the same star. I must therefore bring the star to the western edge of the horizon and turn the globe forward from east to west, one hour by the dial; the degree of the ecliptic now cut by the western edge of the horizon is the 20th of Gemini; consequently, in the interval from May 29th to June 11th, the sun has moved eastward in the ecliptic from the 7th to the 20th degree of Gemini—13 degrees.

CHAPTER V.

Imaginary Circles on the Celestial Globe.

158. The following circles have been already described; point them out on the globe: viz.—the equinoctial, the ecliptic, the tropic of Cancer, the tropic of Capricorn.

159. What are circles of declination?

Small circles parallel to the equinoctial. They are not described on all celestial globes, but every heavenly body is supposed to have such a circle passing through it.

160. What are circles of right ascension?

The meridians or circles passing through the poles of the heavens and cutting the equinoctial at right angles, are called also circles of right ascension. They are not described on all celestial globes, but every heavenly body is supposed to have such a circle passing through.

161. What are poles, mathematically considered?

To every great circle of a sphere there are, on that sphere, two points, each of which is exactly 90° from every part of it; these two points are called the poles of that great circle. The poles of the heavens are therefore the poles of the *equinoctial.*

162. Are there not two other poles marked on a celestial globe?

Yes; the poles of the ecliptic.

163. Show them, and state at what distance they are from the poles of the equinoctial.

Because the ecliptic crosses the equinoctial at an angle of $23\frac{1}{2}$ degrees, the poles of the ecliptic are $23\frac{1}{2}$ degrees from those of the equinoctial.

164. What are the colures?

Two large circles passing through the poles of the heavens; one of them passes through the two equinoctial points and is called the equinoctial colure; the other passes through the two solstitial points and is called the solstitial colure. By them the whole heavens is divided into four equal portions.

165. Show them.

166. What are circles of celestial longitude? and show them.

Circles passing through the poles of the ecliptic and cutting the ecliptic at right angles. Every heavenly body is supposed to have such a circle passing through it.

167. What are parallels of celestial latitude? and show them.

Small circles parallel to the ecliptic. Every heavenly body is supposed to have such a circle passing through it.

168. What is the arctic circle? and show it.

A small circle parallel to the equinoctial, being $66\frac{1}{2}°$ distant from it, and $23\frac{1}{2}°$ distant from

its north pole; it consequently passes through the north pole of the ecliptic.

169. What is the antarctic circle? and show it.

A small circle parallel to the equinoctial, being $66\frac{1}{2}°$ distant from it, and $23\frac{1}{2}°$ distant from its south pole; it therefore passes through the south pole of the ecliptic.

170. What is the derivation of the words "arctic" and "antarctic"?

Greek *arktos*, a bear; *anti*, opposite to.

CHAPTER VI.

Measurement of Time.

171. How is time measured?

By reckoning the oscillations of a pendulum.

172. What is a pendulum?

Any body so suspended that it may be made to swing forwards and backwards may be called a pendulum; but the pendulums of time-pieces are usually small bars of metal with a weight attached, and an apparatus for continuing the motion.

173. What do you mean by oscillations?

The swinging forwards and backwards.

174. Why is a pendulum well adapted to the purpose of measuring time?

Because at the same place, and in the same temperature, a pendulum, properly adjusted, always takes the same time in swinging to and fro, *i. e.* its successive oscillations are all performed in equal times.

175. How is this principle applied to the measurement of time?

Since the times of the oscillations are all the same, the time of *any number* of oscillations is an invariable standard of duration. Suppose we wish to ascertain whether the same period of time always elapses from the appearance of any

heavenly body upon the meridian of a place, until its next appearance upon the same meridian, we can do so by reckoning the oscillations of a pendulum. If we find that the *same* number of oscillations always takes place between *any* two of those appearances, we conclude that the period of time elapsing between them is always of the same length; such period, therefore, is an *invariable* standard of duration. If, on the contrary, we find that the number of oscillations is *not* the same, then we conclude that such period of time is variable, and the amount of its variations may also be found in like manner by the pendulum.

176. What is a year?

That period of time in which the sun completes his circuit of apparent motion in the heavens, and returns again to the place in which he was at its beginning.

177. Are there not several kinds of years?

Yes (as will be subsequently shown); but the one which is universally adopted as a measure of time, is the period which elapses between the sun's appearance in either equinox and his reappearance in the same equinox. It is called indifferently the equinoctial, the tropical, or the civil year.

178. But the civil year does not commence when the sun is in either of the equinoxes: on the 1st of January the sun is in the 10th degree of Capricorn; is not this difference of consequence?

No; the *length* of the year being accurately fixed, its commencements will always be at very

nearly the same distance from the equinoxes, which is just as convenient as if it coincided with either of them.

179. What is a day?

The term day has various significations according to its application.

180. Name some.

The sidereal day, the solar day, day (in opposition to night), the civil day.

181. What is a sidereal day?

The period of time that elapses from the appearance of a fixed star on the meridian of a place, to its reappearance on the meridian of the same place; *i. e.* the period of one entire apparent revolution of the heavenly sphere; or truly, the period of one entire *actual* rotation of the earth.

182. Is a sidereal day a uniform period, that is, are all sidereal days of the same length?

It *is* a uniform period; all sidereal days *are* of the same length.

183. How is the sidereal day divided?

Into 24 equal parts, called sidereal hours, each hour into 60 equal parts, called sidereal minutes; each minute into 60 equal parts, called sidereal seconds.

184. Is not a sidereal day called also an astronomical day?

Yes; and the pendulum of an astronomical clock is made of such a length as to oscillate exactly once in a sidereal second.

185. What is a solar day?

The period of time which elapses between any

two successive appearances of the sun on the meridian of the same place.

186. Is a solar day a uniform period; that is, are all solar days of the same length?

No; the length of the solar day is continually varying; but the variations succeed each other regularly, and are all completed in a year.

187. Which is the longer, a sidereal day, or a solar day?

A solar day.

188. What is the reason?

Suppose the sun and some star to be on the meridian at the same moment; the sidereal day will be completed when the star, by one complete revolution of the heavenly sphere, is again brought to the same meridian: but the sun will not then come to the meridian at the same moment; for, during this interval, he has moved *eastward* in the ecliptic about one degree; consequently the revolution of the heavenly sphere *westward* must continue a little longer before the sun's *new* place is thereby brought to the meridian. Therefore the solar day is a little longer than the sidereal day.

189. What is the cause of the variable length of the solar day?

There are two causes: viz., the obliquity of the ecliptic and the sun's unequal motion in it; for in some parts of his annual circuit his apparent motion is faster than in others. If the sun moved in the equinoctial instead of in the ecliptic, and if he always moved *at the same rate*, then all solar days would be of the same length.

190. Are there not two kinds of solar days?
Yes; the *true* solar day, and the *mean* solar day.

191. What is a *true* solar day?
That variable day which has just been described; *i. e.* the actual period that elapses between two successive appearances of the sun on the meridian of the same place.

192. What is a *mean* solar day?
The period of time which *would elapse* between two successive appearances of the sun on the meridian of the same place, if he moved at a uniform rate in the equinoctial, instead of moving, as he does, at different rates in the ecliptic. It is the *average* length of a day throughout the whole year, and is always of the *same* length.

193. How is the *mean* solar day divided?
Into 24 equal parts called hours, each hour into 60 equal parts called minutes, and each minute into 60 equal parts called seconds.

194. What is meant by the term "noon?"
True or *apparent* noon is the precise moment when the sun is on the meridian of a place. *Mean* noon signifies the moment that he would be there if he moved in the equinoctial as just described.

195. Are watches and clocks made to show the divisions of the true solar day or those of the mean solar day; that is, does an accurate timepiece mark 12 o'clock at apparent (true) noon, or at mean noon?

Most time-pieces are constructed to keep *mean* solar time, and mark 12 o'clock at *mean* noon. The French, however, use the *true* solar day ; and, as that is variable, their time-pieces require to be frequently regulated to accord with those variations.

196. When does a sun-dial show 12 o'clock?

At apparent (true) noon.

197. Is a mean solar day longer or shorter than an apparent (true) solar day?

Because the mean solar day is an *average* of the true solar days throughout the year, the true solar day, during some portions of the year, is shorter, and during others longer, than the mean solar day: thus from Dec. 24th to April 15th, and from June 15th to September 1st, the mean time is always *before* the apparent time ; and an accurate time-piece shows noon *before* a sun-dial. From April 15th to June 15th, and from September 1st to December 24th, the mean time is always *behind* the apparent time; and an accurate time-piece does not show noon until *after* a sun-dial.

198. What is meant by the "Equation of Time at Noon?"

The difference between the lengths of the *mean* solar day and the *true* solar day ; *i. e.* the time by which the time-piece is before the sun-dial, or the sun-dial before the time-piece, in showing noon.

199. When is this difference the greatest?

The difference itself differs slightly in different years; but in 1841, it was the greatest on

November 3d, when the sun-dial showed 12 o'clock nearly 16 minutes 18 seconds before the time-piece.

200. What is the equation of time on the four days just mentioned?

Nothing; the clock and the sun-dial mark noon at the same instant, because the mean and the true solar days are of the same length.

201. Does the equation of time for any day differ in different years?

Yes, very slightly, owing to the precession of the equinoxes (hereafter explained).

202. Which is the longer, a *mean* solar or a sidereal day?

A mean solar day. A sidereal day consists of 23 hours 56 minutes 4 seconds of mean solar time.

203. What is the length of an equinoctial (tropical or civil) year?

It varies slightly; but its average or mean length is 365 days 5 hours 48 minutes 51½ seconds of mean solar time.

204. What is the meaning of the term day, as used in opposition to night?

It signifies the duration of light, or that period of time during which the sun is above the horizon of a place.

205. What is the meaning of the term night?

The duration of darkness, or that period of time during which the sun is below the horizon of a place.

206. Do the days and nights vary in length at the *same* place?

Yes, according to the sun's declination.

207. Does the *same* day vary in length at different places?

Yes, according to the latitudes of those places.

208. What is a civil day?

A day considered with respect to its commencement, for the purpose of regulating the ordinary affairs of life. It differs in different countries. Most of the ancient eastern nations reckoned their day from sunrise to sunrise. The Jews and the Greeks reckoned theirs from sunset to sunset. The modern Austrians, Italians, and Chinese do the same. The ancient Egyptians and Romans reckoned their day from midnight to midnight; and this method is followed by the English, French, Dutch, Germans, Spaniards, Portuguese, and Americans. Modern astronomers take the length of the sidereal day as the standard of duration; but consider it to begin at *mean* noon.

CHAPTER VII.

Latitude, Longitude, Right Ascension, and Declination of Heavenly Bodies.

209. WHAT is meant by the latitude of a heavenly body?

Its distance from the *ecliptic* north or south; or that arc of its circle of longitude which is contained between it and the *ecliptic*.

210. How do you find the latitude of a heavenly body by the globe?

Place the quadrant of altitude upon the globe so that it may pass through the star, 0° being on the ecliptic and 90° on its pole. That degree of the quadrant which is directly over the star shows its latitude.

EXAMPLES.—Required the latitude of the following stars:

α, or Altair, in Aquila, 29½° N.
β, or Rigel, in Orion.
α, or Arcturus, in Boötes.
α, or Dubbe, in Ursa Major.
α, or Fomalhaut, in Piscis Australis.
α, or Cor Hydræ, in Hydra.

211. What is meant by the declination of a heavenly body?

Its distance from the *equinoctial*, north or

south; or that arc of its meridian which is contained between it and the equinoctial.

212. How do you find the declination of a heavenly body by the globe?

Bring the body to the brass meridian, and observe what degree is above it.

EXAMPLES.—Required the declination of the following stars:

α, or Capella, in Auriga, $45\frac{1}{2}°$ N.
α, or Betelgeuse, in Orion.
β, or Rigel, in Orion.
α, or Sirius, in Canis Major.
α, or Procyon, in Canis Minor.
α, or Scheder, in Cassiopeia.

213. Since the sun appears to be in continual motion, he is not represented on the globe like a star: how then do you find his declination on any given day of the year?

On the wooden horizon there are two contiguous circles, one representing the ecliptic divided into signs and degrees, the other representing the months of the year divided into days. By comparing these, I find the sun's place in the ecliptic on the given day. I then find that point of the ecliptic itself, bring it to the brass meridian, and observe the degree above it.

214. What is the sun's declination on May the 10th?

By comparing the circles on the wooden horizon, I find that, on May the 10th, the sun is in the 20th degree of Taurus. Bringing that

degree of the ecliptic to the brass meridian, I find his declination on that day to be $18\frac{1}{2}°$ N.

EXAMPLES.—Required the sun's declination on the following days: March 21st, May 1st, June 21st, August 10th, September 23d, November 30th, December 21st, and January 5th.

215. What is meant by the longitude of a heavenly body?

Every heavenly body is supposed to have a circle of longitude passing through it, and this circle of course intersects the ecliptic. The longitude of a heavenly body is the distance of this point of intersection from the 1st degree of Aries, measured *eastward* along the ecliptic, or an arc of its parallel of latitude contained between it and the circle of longitude which passes through the 1st degree of Aries, measured *eastward*.

216. How is the longitude of a heavenly body found by the globe?

Place the quadrant of altitude on the globe so that it passes through the pole of the ecliptic and the given star, and observe through what point of the ecliptic it passes; the distance of that point from the 1st degree of Aries, reckoned *eastward*, is the longitude required.

EXAMPLES.—Find the longitude of those stars given as examples to Question 210.

217. How is the sun's longitude on any given day to be found by the globe?

Find his place in the ecliptic by comparing the circle of months and the circle of signs on the

wooden horizon; then reckon the distance of that point *eastward* from the 1st degree of Aries. The sun's longitude is generally expressed in signs and degrees.

218. What is the sun's longitude on May the 10th?

I find, by comparison of the two circles, that the sun is then in the 20th degree of Taurus; consequently his longitude is 1 sign 20 degrees.

EXAMPLES.—Find the sun's longitude on the days given as examples to Question 214.

219. What is meant by the right ascension of a heavenly body?

The distance, measured eastward along the equinoctial, from the 1st degree of Aries, of that degree of the equinoctial which rises at the same moment as the body, in a right sphere.

220. How is the right ascension of a star to be found by the globe?

In two ways. Either by bringing the star to the brass meridian, and observing what degree of the equinoctial is then under it; or, more clearly, by putting the globe in a right sphere, bringing the star to the eastern edge of the horizon, and observing what degree of the equinoctial is then cut by the same edge.

221. Find, by both these methods, the right ascension of α, or Capella, in Auriga?

Seventy-five degrees.

222. Is not right ascension usually expressed in time?

Yes; the time which elapses between the rising

of the 1st degree of Aries and that of the star, in a right sphere.

223. How are degrees of the equinoctial to be changed into time?

Since the whole equinoctial, or 360°, revolves once in 24 mean hours, it revolves through 15° in one hour, and through 1° in four minutes.

224. What time corresponds to 75°?

Five hours; in a right sphere, Capella rises five hours after the first degree of Aries.

EXAMPLES.—Find the right ascensions of those stars given as examples to Question 212.

225. How do you find, by the globe, the sun's right ascension on any given day?

By first finding the sun's place in the ecliptic, and then bringing that place to the brass meridian; or, if the globe has been previously placed in a right sphere, by bringing it to the eastern edge of the horizon; and then observing the degree of the equinoctial cut by the meridian, or the horizon.

EXAMPLES.—Find the sun's right ascension on those days which are given as examples to Question 214.

226. Can the latitude or longitude, the declination or right ascension of the moon and the planets be found by the globe?

No; because from their continual change of situation they cannot be depicted on the globe as the stars are.

227. If the latitude and longitude of a

heavenly body be given, can you find it, or its place, upon the celestial globe?

Yes; I place the 90th degree of the quadrant of altitude on the pole of the ecliptic, and cause the graduated edge of it to correspond with the given longitude on the ecliptic; then, under the given latitude on the quadrant, will be found the required body, if it be a star; or its place, if it be a planet or the moon.

EXAMPLES.—What stars have the following latitudes and longitudes?

Latitude.	Longitude.
$31\frac{1}{4}°$ S.	2 signs $14°$
23 N.	2 signs $19°$
$44\frac{1}{4}$ N.	7 signs $9\frac{1}{2}°$
21 S.	11 signs $1°$

At mean noon, on the first of January, 1841, the latitudes and longitudes of the planets Mercury, Venus, Mars, and Jupiter, were as follow, by the *Nautical Almanac*—show their places on the globe:—

Mercury	lat. $1\frac{1}{2}°$ N. :	long.	7 signs	$3\frac{1}{2}°$
Venus	lat. $2\frac{3}{4}$ S. :	long.	0 sign	$18\frac{1}{2}°$
Mars	lat. $1\frac{3}{4}$ N. :	long.	5 signs	$9\frac{3}{4}°$
Jupiter	lat. $0\frac{3}{4}$ N. :	long.	8 signs	$2\frac{3}{4}°$

At midnight, on January 1st, 1841, the moon's longitude was 0 sign $24\frac{1}{2}°$ and her latitude $4\frac{3}{4}°$ N. Show her place on the globe.

228. If the declination and right ascension of a heavenly body be given, can you find it, or its place, on the celestial globe?

Yes; if the right ascension is given in time,

I first change that time into degrees, by reducing it to minutes, and dividing those minutes by 4. I then look on the equinoctial for the degree thus found, and bring it to the brass meridian: then under the given declination will be found the required body, if a star; or its place, if the moon or a planet.

EXAMPLES.—What stars have the following right ascensions and declinations?—

Right Ascensions.	Declinations.
1 hour 40 min. (or 25°)	$19\frac{3}{4}$° N.
5 hours 45 min.	45 N.
7 hours 33 min.	$28\frac{1}{2}$ N.
6 hours 32 min.	16 S.

At mean noon, on June 1st, 1841, the right ascensions and declinations of the planets Saturn and Georgium Sidus were as follow, by the *Nautical Almanac*:—show their places on the globe:—

	Right Ascensions.	Declinations.
Saturn	18 hrs 5 min.	$22\frac{1}{4}$° S.
Georgium Sidus	23 hrs 39 min.	3 S.

At five o'clock in the evening of the same day, the moon's right ascension was 15 hours, and her declination $22\frac{1}{2}$° South. Show her place on the globe.

CHAPTER VIII.

Variations in the length of the day (considered as the period of light) at the same place.

229. Have you not stated that the length of the day varies at the same place?

Yes, it varies according to the sun's declination.

230. Is this statement true of *all* places on the earth?

No; places on the equator, to which the heavens, consequently, are presented in a right sphere, have the sun above their horizon for 12 hours, and below it for the same time on every day of the year, *i.e.* during every apparent revolution of the heavenly sphere.

231. Why?

Because in whatever part of the ecliptic the sun may be, his circle of daily rotation round the earth is equally divided by the horizon of such places, *i.e.* his diurnal and nocturnal arcs are, each of them, a semicircle.

232. What do you mean by the sun's diurnal arc?

That portion of his circle of rotation, through which he moves *above* the horizon of a place.

233. What do you mean by the sun's nocturnal arc?

That portion of his circle of rotation through which he moves *below* the horizon of a place.

234. Show, by the globe, that, at places on the equator, the days and nights are equal on any four days of the year; say February 1st, May 1st, November 1st, and August 1st.

I first place the globe in a right sphere, by putting the poles in the horizon. I then find the sun's place to be—

On Feb. 1st, the 13th degree of Aquarius.
On May 1st, the 10th degree of Taurus.
On Aug. 1st, the 9th degree of Leo.
On Nov. 1st, the 9th degree of Scorpio.

Successively bringing each of these points of the ecliptic to the eastern edge of the horizon, setting the dial to 12, and turning the globe westward, until the same point comes to the *western* edge of the horizon, I find, in each case, that exactly 12 hours are passed over by the dial.

235. Are there any other places, besides those on the equator, at which the length of the day does not vary?

Yes; it does not vary at either of the poles. At either pole there is but one day and one night in the year; and, every year, the day is of the same length, and the night is of the same length, at the same pole.

236. Why?

Persons who live at either pole (if there are any) view the heavens in a parallel sphere; and in a parallel sphere, half the ecliptic (which is the

sun's annual course) is above the horizon, and half below it.

237. Place the globe as a north parallel sphere, and show that such is the case.

I elevate the north pole of the heavens 90° above the wooden horizon, which makes it represent the horizon of the north pole of the earth. In this position the equinoctial coincides with the horizon, half the ecliptic is above it, and half below it. Therefore, on every day that the sun is in any part of the ecliptic which is now above the horizon, *i.e.* whenever he is in north declination, his entire circle of rotation is *above* the horizon, and he does not set. But the sun is always in north declination from the equinox of Aries to the equinox of Libra, and he is in those equinoxes on March 21st and September 23d. Consequently, uninterrupted daylight continues at the north pole from March 21st to September 23d; for the sun does not once set during that interval.

238. What appearance does the sun present to the north pole *on* those two days of the year?

Having no declination, his circle of rotation coincides with the horizon, along which he appears to skim without rising or setting.

239. Is that statement strictly true?

It is true that he *does* on those days skim along the horizon without rising above it: but it is not true that he *appears* to do so.

240. Why does he not appear to do so?

The sun's apparent place is affected by two causes called parallax and refraction (subsequently

explained), by the combined agency of which he is made to appear *in* the horizon of the pole when he is in reality half a degree below it: consequently, on those two days when he is really *in* the horizon, and his circle of rotation actually *coincides* with it, that circle appears to be half a degree above it.

241. Can you show, by the globe, that there is but one day and one night in the year at the south pole also; and that the day is there always of the same length, and the night of the same length?

Yes; by elevating the south pole 90°, it may be seen, that whenever the sun's declination is *south*, his entire circle of rotation is above the horizon. But the sun is in south declination from the equinox of Libra to the equinox of Aries. Consequently, he does not set to the south pole from September 23d to March 21st; whilst *on* those days he in reality skims along the horizon without rising or setting, though, owing to the combined agency of parallax and refraction, he appears to be half a degree above it.

242. When do the nights occur at the poles?

The day at one pole is the night at the other. Consequently, at the north pole, night lasts from September 23d to March 21st, during which period the sun does not once rise: similarly, at the south pole, night lasts from March 21st to September 23d, during which period the sun does not once rise.

243. What is the length of the day, and of the night, at each pole?

At the north pole, the daylight lasts 186 days

(or revolutions of the sphere), and the night 179 days. At the south pole, daylight continues 179 days, and night 186 days.

244. You have shown that the length of the day does not vary at the equator and at the poles —does it vary at all other places?

It is continually varying throughout the whole year at *every* other place; and at all places, not in the frigid zones, it varies in the same manner: but at places in the frigid zones it varies in a different manner.

245. In what manner does the length of the day vary at any place in north latitude, but not in the frigid zone?

At any such place, the days are *shorter* than the nights, during that period of the year when the sun's declination is *south*, and the days are *longer* than the nights during that period of the year when the sun's declination is *north*. The shortest day and longest night occur on December 21st, when the sun is in the southern solstice. The days increase and the nights decrease from that time until March 21st, when the sun is in the equinox of Aries; on that day they are equal, each being 12 hours long. From March 21st, the days continue to increase, and the nights to decrease, until June 21st, when the sun is in the northern solstice, and then the longest day and shortest night occur. From June 21st, the days decrease and the nights increase, until September 23d, when the sun is in the equinox of Libra, and they are again equal, each being 12 hours long. From September 23d the days

continue to decrease, and the nights to increase, until December 21st, when the sun being again in the southern solstice, the shortest day and longest night again occur.

246. What is the cause of this variation according to the declination ?

The sun's circles of daily rotation are very nearly parallel to the equinoctial. Now, when the north pole is elevated, the position of the horizon with respect to these circles is such that it divides them unequally, the less portion being above it when the sun's declination is *south*, and the greater part being above it when the sun's declination is north.

247. Illustrate, by the globe, this variation in the length of the day, as it occurs at London (lat. $51\frac{1}{2}$ N.).

I first make the wooden horizon represent the horizon of London, by elevating the north pole $51\frac{1}{2}$ degrees above its north point. I then bring the first degree of Capricorn (which is the southern solstice) to the eastern edge of the horizon, and set the dial to 12. I turn the globe from east to west, until the same degree is thereby brought to the western edge; and, observing the dial, I find that it has passed over about $7\frac{3}{4}$ hours. The shortest day (Dec. 21st) is therefore $7\frac{3}{4}$ hours long; and, consequently, the longest night is $16\frac{1}{4}$ hours long.

Proceeding in the same manner with the first degree of Aries, I find that the dial passes over 12 hours. The day and the night are therefore, each of them, 12 hours long on March 21st.

Proceeding in the same manner with the first degree of Cancer (the northern solstice), I find that the dial passes over about $16\frac{1}{4}$ hours. The longest day (June 21st) is therefore $16\frac{1}{4}$ hours long, and consequently the shortest night is $7\frac{3}{4}$ hours long.

Proceeding in the same manner with the first degree of Libra, I find that the dial again passes over 12 hours; therefore, on Sept. 23d, the day and the night are again, each of them, 12 hours long.

248. In what manner do the days vary at a place in *south* latitude, but not in the frigid zone?

In a similar manner, but with this difference; that, in consequence of the elevation of the *south* pole, the horizon divides the sun's circles of rotation in such a manner that the less portion is above it when his declination is north, and the greater portion when his declination is south. Consequently a place in south latitude has the days shorter than the nights, when, to a place in north latitude, they are longer; and the days longer than the nights when, to a place in north latitude, they are shorter; the shortest day being on June 21st, and the longest on Dec. 21st.

249. Express the substance of the four preceding answers more concisely.

At any place (neither on the equator nor within the frigid zones) the days are *longer* than the nights when the sun's declination is in the *same direction* as the latitude, and shorter than the nights when the sun's declination is in a direction *contrary* to the latitude.

On Dec. 21st the longest day and shortest night occur in south latitude; and the shortest day and longest night in north latitude. On June 21st the longest day and shortest night occur in north latitude, and the shortest day and longest night in south latitude. On March 21st and Sept. 23d equal day and night occur. From Dec. 21st to June 21st the days are increasing and nights decreasing in north latitude, whilst the days are decreasing and the nights increasing in south latitude. From June 21st to Dec. 21st the days are decreasing and nights increasing in north latitude, whilst the days are increasing and nights decreasing in south latitude. At two places in the same degree of latitude, but in opposite hemispheres, the duration of day at the one is the duration of night at the other on *any* and *every* day of the year.

250. How may the length of any given day and night, at any given place (not in the frigid zones) be found by the globe?

Rectify the globe for the given place; find the sun's place in the ecliptic on the given day; bring it to the eastern edge of the horizon; set the dial to 12; turn the globe *westward* until the sun's place is thereby brought to the western edge of the horizon: then the time passed over by the dial shows the length of the day. Subtract the time, thus found, from 24 hours, and the remainder is the length of the night.

EXAMPLES.—What is the length of the day and of the night at the following places on the given days?—

At Madeira, on March 1st.
At Rio Janeiro, on June 3d.
At Bombay, on May 7th.
At Pekin, on Sept. 25th.
At Constantinople, on October 5th.
At Barbadoes, on Nov. 7th.
At Quebec, on Aug. 9th.
At Canton, on Feb. 2d.

At Paris, St. Petersburg, and Madeira, on the longest day in north latitude.

At Cape of Good Hope, Cape Horn, and Buenos Ayres, on the longest day in south latitude.

251. How can you find the time of sunrise and of sunset?

By halving the length of the day; for instance, when the length of the day is 15 hours, the sun rises 7½ hours before noon, *i.e.* at half-past four; and sets 7½ hours after noon, *i.e.* at half-past seven.

Examples.—Find the time of sunrise and of sunset at the places given in the preceding question.

252. At what time does the sun always rise and set at any place on the equator?

He always rises at 6 o'clock in the morning, and always sets at 6 o'clock in the evening.

253. Why?

Because at such a place the day is always invariably 12 hours long.

254. How can the time of sunrise and of sunset be found by the globe?

Rectify the globe ; find the sun's place ; bring it to the brass meridian ; and set the dial to 12. Turn the globe westward until the sun's place is thereby brought to the western edge of the horizon : the hours passed over by the dial show how long *after* noon the sun sets, and consequently how long *before* noon he rises, on the given day.

EXAMPLES.—The same as those to Question 251.

Here let Questions 204 to 217, on the Terrestrial Globe, be again proposed to the pupil, and let him be required to work the same examples by the Terrestrial Globe.

255. You said that the length of the day varies in a different manner at any place in either of the frigid zones—how so ?

For one portion of the year the sun does not *set* during several apparent revolutions of the heavens ; for another portion he does not *rise* during several apparent revolutions of the heavens ; and for two other portions of the year he rises and sets with every apparent revolution of the heavens, *i.e.* every 24 hours.

256. On what do the respective lengths of these portions depend ?

On the relation between the sun's declination and the colatitude of the place.

257. Are not the terrestrial polar circles the boundaries of the frigid zones ?

They are.

258. How far are they from the equator ?

The arctic circle is $66\frac{1}{2}°$ north of it, and the antarctic circle is $66\frac{1}{2}°$ south of it.

259. Suppose a place to be *on* the arctic circle, and show by the globe in what manner the length of the day, at that place, depends upon the sun's declination.

Such a place is in $66\frac{1}{2}°$ north latitude. Having rectified the globe to this latitude, it may be seen, as the globe is turned from east to west, that every point of the ecliptic comes *above* and goes *below* the horizon except two; viz., the first degree of Cancer, which does not *go below*, and the first degree of Capricorn, which does not come above it. Therefore the days of the year vary in length at this place in the same *manner* as at any other place nearer the equator, *with* this exception, that on June 21st the *day* lasts 24 hours, there being no night whatever; and on Dec. 21st the *night* lasts 24 hours, there being no day whatever.

260. Can the same thing be shown with respect to a place on the antarctic circle?

Yes; if the *south* pole is elevated $66\frac{1}{2}°$, it will be seen that the 1st degree of Capricorn does not *go below* the horizon, and that the 1st degree of Cancer does not *come above* it. Consequently, at such a place, on December 21st, the *day* lasts 24 hours, and there is no night: on June 21st the *night* lasts 24 hours, and there is no day.

261. What is the colatitude of places situated on the polar circles?

Twenty-three and a half degrees.

262. What is the sun's declination on June 21st, when he is in the 1st degree of Cancer; and on December 21st, when he is in the 1st degree of Capricorn?

On the former day, $23\frac{1}{2}°$ north, and on the latter, $23\frac{1}{2}°$ south.

263. Then, what relation exists between the sun's declination and the colatitude when this day, or this night, of 24 hours each, takes place?

The day of 24 hours takes place when the sun's declination, in the *same* direction, is equal to the colatitude; and the night of 24 hours takes place when the sun's declination, in the *opposite* direction, is equal to the colatitude.

264. Are there any places besides those through which either of the polar circles passes, which ever have the day and the night exactly 24 hours long each?

No; but those *in* either of the frigid zones have the day longer than 24 hours at one period of the year, and the night longer than 24 hours at another period of the year.

265. Now take a place *within* the north frigid zone; say, for instance, in latitude 75° north; and show in what manner the comparative length of the day there depends upon the sun's declination.

Having elevated the north pole 75°, I turn the globe upon its axis, and perceive that a considerable portion of the ecliptic does not go below the horizon; viz., all that part between the 10th degree of Taurus and the 20th of Leo; therefore, whenever the sun is between these

points, he does not set in latitude 75° north. Referring to the circles of signs and months, I find that the sun is in those points on April 30th, and August 12th; therefore, during the interval between those days, the sun does not set in latitude 75° north, and uninterrupted daylight occurs.

266. How does this depend upon the sun's declination and the colatitude of the place?

By bringing those two points of the ecliptic to the brass meridian, I find the declination of each to be 15° north, which is exactly the colatitude of the place. Consequently, the longest day at any place in the north frigid zone begins on that day of the year, between March 21st and June 21st, when the sun's declination is equal to the colatitude, and terminates on the next day of the year, that the sun has the same declination; during the interval, because the sun's declination exceeds the colatitude, he does not once set, and uninterrupted daylight occurs at that place.

267. Turn the globe again: is there not a portion of the ecliptic which does not come above the horizon?

Yes; that portion which is between the 11th degree of Scorpio and the 18th degree of Aquarius. Whenever the sun is between these points, which he is from the 3d of November to the 6th of February, the sun does not rise in 75° north latitude. These two points are, each of them, in 15° *south* declination. Consequently, the longest night at any place in the north frigid zone, begins on that day of the year, between

September 23d and December 21st, when the sun's declination is equal to the colatitude, and terminates on the next day that the sun has the same declination: during the interval, because the sun's declination *in the opposite direction* exceeds the colatitude, he does not once rise, and uninterrupted night occurs.

268. Can the same result be shown by the globe with respect to places in the *south* frigid zone?

Yes; by elevating the south pole, and proceeding in precisely the same manner. But we shall find this difference, that the longest day begins on some day between September 23d and December 21st, and the longest night on some day between March 21st and June 21st.

269. During what portions of the year does the sun rise and set every 24 hours?

Keeping the globe in the same position, I again turn it, and perceive that every part of the ecliptic, except those two portions just described, comes *above* the horizon, and goes *below* it. Therefore, the sun rises and sets on all those days of the year when his declination in either direction is less than the colatitude of the place, which is the case from the ending of the longest night to the beginning of the longest day, and from the ending of the longest day to the beginning of the longest night.

270. Can you express the substance of the preceding answers more concisely?

Yes; the longest *day* at any place in the frigid zones begins and ends when the sun's de-

clination, *in the same direction*, is equal to the colatitude of the place, which it is twice in the year: the longest night begins and ends when the sun's declination, in *the opposite direction*, is equal to the colatitude, which it is twice in the year. In the two intervals which occur between these periods the sun rises and sets with every apparent revolution of the heavenly sphere.

271. How do you find, by the globe, the length of the longest day at any place in the frigid zones?

Find the colatitude of the place, and count it on the brass meridian in the *same direction* as the latitude; turn the globe, and observe what two points of the ecliptic pass under this degree on the brass meridian; and find, by the circles of signs and months, on what days of the year the sun is in those points.

272. What is the length of the longest day in latitude 78° north?

In this instance the colatitude is 12°; the two points of the ecliptic which pass under the 12th degree of north declination, are the 2d of Taurus and the 29th of Leo; the sun is in these points on April 22d and August 22d; the former is, therefore, the beginning, and the latter the ending, of the longest day, which lasts 122 days, or revolutions of the sphere.

273. How do you find the length of the longest night?

In the same manner, except that, as the sun's declination is now in a direction opposite to the

latitude, the colatitude must be counted on the brass meridian in the opposite direction.

274. What is the length of the longest night in latitude 78° N.?

The two points of the ecliptic which pass under the 12th degree of *south* declination are the 6th degree of Scorpio and the 28th degree of Aquarius; the sun is in these points on October 30th and February 17th; the former therefore is the beginning and the latter the ending of the longest night, which consequently lasts 110 days.

275. During what periods of the year does the sun rise and set every twenty-four hours in the same latitude?

From the 17th of February to the 22d of April, *i. e.* 64 days; and from the 22d of August to the 30th of October, *i. e.* 69 days; both periods together making 133 days. The same result may be obtained by adding the lengths of the longest day and the longest night, and subtracting their sum from 365.

Examples.—Find the beginning and ending of the longest day and of the longest night, the duration of each, and the periods during which the sun rises and sets with every revolution of the sphere at places in the following latitudes:—

71½° N. 69° N. 81° N. 76° S. 82½° S.

276. Is not the apparent motion of the celestial sphere, and consequently the rising and setting of the sun, caused by the actual rotation of the earth from west to east?

They are.

277. Then how is this length of day and night at a place in the frigid zones really caused?

When the sun's declination in the *same* direction exceeds the colatitude of the place, the earth revolves many times on its axis without carrying that place *below* the boundary of light and darkness; and when the sun's declination, in the *opposite* direction, exceeds the colatitude, the earth revolves many times without bringing that place *above* the boundary of light and darkness.

278. Can you illustrate this by the terrestrial globe—say for the North Cape (lat. 71½° N.)?

Yes; the colatitude is 18½° N. I elevate the north pole to 18½°, being the sun's declination at the commencement of the longest day. Now, as I turn the globe from West to East, it may be seen that the North Cape does not *go below* the boundary of light and darkness (now represented by the wooden horizon); nor will it do so during the whole period that the sun's declination northward is greater than 18½°, as may be seen by elevating the pole to any greater declination. If I elevate the south pole 18½°, to correspond with the sun's declination at the commencement of the longest night, it may be seen that the North Cape does not *come above* the boundary of light and darkness; nor will it do so during the whole period that the sun's declination *southward* is greater than 18½°, as may be seen by elevating the pole to any greater declination.

279. If any day, between March 21st and June 21st, be given, can you find in what

degree of north latitude that day is the beginning of the longest day?

Yes; find the sun's declination on the given day; and its co-declination is equal to the latitude required.

280. In what latitude is the same day the beginning of the longest night?

In the same degree of *south* latitude.

281. In what latitude is the 14th of May the beginning of the longest day, and in what latitude is it the beginning of the longest night?

I find the sun's declination on that day to be $18\frac{1}{2}°$ N.; its co-declination is therefore $71\frac{1}{2}°$. Consequently to all places in $71\frac{1}{2}°$ north latitude, May 14th is the beginning of the longest day; and to all places in $71\frac{1}{2}°$ south latitude, it is the beginning of the longest night.

282. If any day between the 23d of September and the 21st of December be given, how can you find in what latitude it is the beginning of the longest day, and in what latitude it is the beginning of the longest night?

In precisely the same way, only observing that, as the sun's declination is then south, it is the beginning of the longest day in *south* latitude, and the beginning of the longest night in *north* latitude.

EXAMPLES.—In what latitudes are the following days the beginning of the longest day and the beginning of the longest night:

April 4th, May the 7th, June 2d,
Oct. 13th, Nov. the 15th, Dec. 1st?

CHAPTER IX.

Variable length of the *same* day (as used in opposition to night) at *different* places.

283. Did you not state, in answer to question 207, that the *same* day varies in length at *different* places?

Yes; according to the latitudes of those places.

284. Is the same day longer in a low or in a high latitude?

That depends upon the *direction* of the sun's declination on that day.

285. In what manner?

If the places are both on the same side of the equator, then on any day, when the sun's declination is in the same direction as the latitudes, *i. e.* both north or both south, the greater the latitude the longer the day; but on any day when the sun's declination is in an *opposite* direction, the greater the latitude the shorter the day.

286. What is the reason that the day is longer in the higher latitude when the sun's declination is in the same direction?

Whenever the *same* day is longer at one place than at another, it must be because a greater portion of the sun's circle of rotation on that day is above the horizon of the former place than

above that of the latter; *i. e.* because his diurnal arc is greater at the former place than at the latter. Now, whenever the sun's declination is in the direction of the elevated pole (*i. e.* of the latitude), the more that pole is elevated the greater the sun's diurnal arc becomes.

287. Show by the globe that such is the case.

Suppose the sun to be in the first degree of Taurus, which he is on April the 20th, and let the latitudes of the two places be 30° N. and 50° N. When I elevate the north pole 30° to correspond with the lower latitude, I find the length of the day (by Quest. 250) to be $12\frac{3}{4}$ hours. When I elevate the same pole 50° to correspond to the higher latitude, I find the length of the same day to be $13\frac{3}{4}$ hours. Consequently, on the 20th of April the sun is above the horizon of a place in 50° north latitude for one hour longer than he is above the horizon of a place in 30° north latitude.

EXAMPLES.—Find the difference in the duration of daylight on the following days in the given latitudes, and state in which daylight is the longer.

April 20th, in latitude 24° N. and 58° N.
May 11th, in latitude 25° N. and 60° N.
Aug. 12th, in latitude 28° N. and 56° N.
Nov. 1st, in latitude 17° S. and 44° S.
Dec. 8th, in latitude 37° S. and 62° S.
Feb. 5th, in latitude 29° S. and 51° S.

288. What is the reason that the day is

shorter in the higher latitude when the sun's declination is in the opposite direction?

When the sun's declination is in the opposite direction to the elevated pole, the more that pole is elevated the *less* his diurnal arc becomes.

289. Show by the globe that such is the case.

Suppose the sun to be in the first degree of Sagittarius, which he is on Nov. 23d, and let the given latitudes be, as before, 30° N. and 50° N. Elevating the north pole 30°, I find the length of the day to be $10\frac{1}{4}$ hours; but, elevating it 50°, I find the length of the same day to be only $8\frac{1}{2}$ hours. Consequently, on Nov. 23d the sun is above the horizon of a place in 50° north latitude for a period of time *shorter*, by $1\frac{3}{4}$ hour, than that for which he is above the horizon of a place in 30° north latitude.

Examples.—Find the difference in the duration of daylight on the following days, in the given latitudes, and state in which it is the shorter.

Oct. 10th, in latitude 23° N. and 49° N.
Nov. 30th, in latitude 17° N. and 53° N.
Feb. 7th, in latitude 27° N. and 62° N.
May 5th, in latitude 19° S. and 52° S.
July 1st, in latitude 25° S. and 48° S.
Aug. 5th, in latitude 18° S. and 58° S.

290. Suppose the places are not on the same side of the equator, at which then is the same day the longer?

It is always the longer at that place the latitude of which is in the same direction as the sun's declination on the given day. If two

places, one in the northern hemisphere the other in the southern, are in the *same degree* of latitude, the length of the *day* at the one is the length of the *night* at the other.

EXAMPLES.—What is the duration of daylight on

May 1st, in latitude 40° N. and 40° S.
Aug. 10th, in latitude 50° N. and 50° S.
Nov. 5th, in latitude 35° N. and 35° S.
Sept. 1st, in latitude 25° N. and 25° S.
Dec. 12th, in latitude 40° N. and 40° S.

291. Does *every* day in the year vary in length according to the latitudes of places?

No; on two days of the year the sun is above the horizons of all places (except the poles) for twelve hours, and below them for the same time.

292. On what two days of the year does this equality of day and night occur?

On March 21st and September 23d, the days when the sun is in the equinoxes.

293. What is the cause of this equality?

When the sun is in either of the equinoctial points, his circle of rotation, on that day, coincides with the equinoctial. But the equinoctial is a *great* circle equidistant from the poles of the heavens, and therefore in whatever position the celestial globe is placed (except a parallel sphere) half that circle is above the horizon, and half below it, as may be shown by elevating the pole to any number of degrees less than ninety. Consequently, when the sun is in the equinoxes, his diurnal and nocturnal arcs are

equal at *every* place on the earth except the poles.

294. What happens at the poles on those days?

In a parallel sphere the equinoctial and the horizon coincide. Therefore when the sun is in the equinoxes, he in reality skims along the horizon of both the poles; though, in consequence of the combined agency of parallax and refraction, he *appears*, on those days, to make his diurnal revolution half a degree above the horizon of each.

CHAPTER X.

The Altitude, the Amplitude, the Oblique Ascension, the Oblique Descension, the Ascensional and Descensional Difference, and the Azimuth of heavenly bodies.

295. You have already defined the zenith of a place to be that point of the heavens which is precisely over that place; and you have stated that it is 90° from every point of the horizon:—at what distance is it from the equinoctial.

Its distance from the equinoctial is equal to the latitude of the place, and in the same direction.

296. Show, by the globe, that such is the case with respect to a place in 50° north latitude.

To make the wooden horizon represent the horizon of such a place, I elevate the north pole 50° above its north point. In this position of the globe, *that* degree of the brass meridian which is 90° above the N. and S. points of the horizon is the 50th to the *north* of the equinoctial. By screwing the quadrant of altitude over this 50th degree, and passing it round the globe, it may be seen that 0 always coincides with the wooden horizon; consequently this 50th degree on the meridian is 90° distant from every part of the horizon.

297. What are azimuth or vertical circles?

Imaginary circles passing through the zenith and the nadir of a place, and therefore cutting its horizon at right angles. Every heavenly body is supposed to have such a circle passing through it.

298. Are they described on the globe?

Since the situation of the zenith depends upon the latitude of the place, they cannot be described on the globe. But when the quadrant of altitude is screwed over that degree corresponding to the latitude of any place, and 0 thereby made to coincide with the wooden horizon, the graduated edge of the quadrant represents a vertical circle at that place.

299. What are almacantars or parallels of altitude?

Imaginary circles parallel to the horizon of a place. Every heavenly body is supposed to have such a circle passing through it.

300. Are they described on the globe?

No; they cannot be, because the position of the horizon varies according to that of the zenith, and that of the zenith varies according to the latitudes of places.

301. What is meant by the zenith distance of a place?

The distance of its zenith from the elevated pole.

302. At what distance is the zenith of a place from the elevated pole?

Because the equinoctial is 90° from the elevated pole, and the distance of the zenith from the equinoctial is equal to the latitude of the

place, its distance from the elevated pole must be equal to the colatitude.

303. **What is meant by the altitude of a heavenly body?**

The height of that body, above the horizon, measured on a vertical circle; or, it is the arc of a vertical circle between the body and the horizon.

304. **What is meant by the meridian altitude of a heavenly body?**

Its altitude when on the meridian of a place: this is the greatest altitude it can have at the same place.

305. **Is the meridian altitude of a body the same, on every day of the year, at the same place?**

That of a fixed star is, because a fixed star has no motion of its own; but that of the sun, the moon, and the planets, is variable.

306. **How do you find the meridian altitude of a fixed star by the globe?**

Elevate the pole to the latitude of the place, and bring the given star to the brass meridian; then count the number of degrees from the star, along the brass meridian, to that point of the horizon (N. or S.) which is nearest to it. The number of degrees, so found, is the star's meridian altitude above that point.

307. **Do not some stars cross the meridian twice during one apparent revolution of the sphere?**

Yes; those stars whose declination, in *the same direction*, exceeds the colatitude of the place.

308. How are these two meridian altitudes of such stars found?

By bringing the star *twice* to the brass meridian, once to that part of it which is above the elevated pole, and once to that part which is below it. In the former case the *greatest* meridian altitude is thereby found; and in the latter the least.

EXAMPLES.—Find the meridian altitudes of the following stars, stating, in each case, whether the star crosses the meridian once only, or twice:—if twice, find both its meridian altitudes.

At London ($51\frac{1}{2}$° N.) and New Orleans (30° N.)

	At London.	At New Orleans.
α in Andromeda.	$65\frac{1}{2}$° above S.P.	87° above S.P.
α (or Sheder) in Cassiopeia.		
α (or Betelgeuse) in Orion.		
α (or Sirius) in Canis Major.		
α (or Dubbe) in Ursa Major.		
β (or Rigel) in Orion.		

α (or Capella) in Auriga at Paris (49° N.)
London ($51\frac{1}{2}$° N.) and Petersburg (60° N.)

At Cape Horn (60° S.)
α (or Acherner) in Eridanus. α in Centaurus.
α (or Capella) in Auriga.

309. When the declination of the star and the latitude of the place are known, may not the meridian altitude be found by calculation?

Yes; by the following rules:—

1st. When the declination and the latitude are in the *same direction*. Add the declination to the colatitude. Their sum (if it does not exceed 90°) is the meridian altitude above that point of

the horizon which is of *contrary* name to the latitude. If the sum exceeds 90°, subtract it from 180°, and the difference is the meridian altitude above that point of the horizon which is the *same* name as the latitude. If the declination is greater than the colatitude, that star does not set, and therefore crosses the meridian twice; then their difference is the *least* meridian altitude above that point which is of the *same* name as the latitude.

2d. When the declination and the latitude are in contrary directions. Subtract the declination from the colatitude; their difference is the meridian altitude above that point which is of *contrary* name to the latitude. If the declination is *greater* than the colatitude, the star does not rise, and their difference shows its *nearest approach* to the horizon when crossing the meridian.

EXAMPLES.—Work the Examples to the preceding question by calculation; the declinations being as follow:—

α in Andromeda,	27° N.	β in Orion,	8½° S.
α in Cassiopeia,	55° N.	α in Auriga,	45½° N.
α in Orion,	7½° N.	α in Eridanus,	58° S.
α in Canis Major,	16° S.	α in Centaurus,	59° S.
α in Ursa Major,	63° N.	α in Auriga,	45½° N.

310. How do you find the *sun's* meridian altitude at any given place on any given day?

Having first found his place in the ecliptic, his meridian altitude may be found, either by the globe, in the manner described (Quest. 306), or by calculation according to the rules (Quest. 309).

EXAMPLES.—Find the sun's meridian altitude

by the globe, and verify it by calculation on the following days at the given places:—

		Lat.
May	9th, at Paris (58° above the S. P.)	(49° N.)
June	7th, at Rio Janeiro	(23° S.)
Sept.	2d, at St. Petersburg	(60° N.)
Nov.	6th, at Buenos Ayres	(34½° S.)
Dec.	30th, at Madras	(13° N.)

311. How do you find the meridian altitude of the moon or a planet at any given place on any given day?

First determine its place on the globe by finding (in a Nautical Almanac) its latitude and longitude, or its declination and right ascension. Mark its place on the globe by sticking a small piece of paper there which will be easily seen. Then the meridian altitude may be found by Quest. 306; or it may be computed by Quest. 309.

EXAMPLES.—The following data are taken from the Nautical Almanac for the time at which the bodies crossed the meridian of Greenwich (51½° N.), on May 1st and November 1st, 1841. Find their meridian altitudes at that place by the globe, and then verify the same by calculation.

			Hrs.	Min.	Dec.
May 1st,	Mercury,	R. A.	1	14	5° N.
	Venus,	R. A.	3	50	25½° N.
	Mars,	R. A.	13	26	7¾° S.
	The Moon,	R. A.	4	43	26¾° S.
Nov. 1st,	Jupiter,	R. A.	17	16	23° S.
	The Moon,	R. A.	22	36	5½° S.

312. What is meant by the amplitude of a heavenly body?

The distance at which it rises or sets to the north or south of the east or west points of the horizon. Or, it is an arc of the horizon contained between the centre of the body and the east point of the horizon (when the body is rising), and between the centre of the body and the west point of the horizon (when the body is setting).

313. Is the amplitude of a body the same on every day of the year at the same place?

The amplitude of bodies which have no motion is: but that of bodies which apparently or actually move is not.

314. What is meant by the oblique ascension or descension of a heavenly body?

The distance—eastward from the 1st degree of Aries, of that degree of the equinoctial which *rises*, or which *sets*, with the given body in an oblique sphere.

315. Is it not generally expressed in time?

Yes, the mean solar time which elapses between the rising or setting of the first degree of Aries and that of the heavenly body.

316. What is meant by the diurnal arc of a heavenly body?

That portion of its circle of rotation which is above the horizon.

317. Is it not generally expressed in time?

Yes, the mean solar time during which the body continues above the horizon. The sun's diurnal arc expressed in time is the length of the day.

318. How do you find, by the globe, the amplitude, the oblique ascension, the diurnal arc, and the oblique descension of a given star at any given place?

Rectify the globe for the given place, and bring the given star to the eastern edge of the horizon; the number of degrees from the east *point* to the star is its *rising* amplitude, and *that* degree of the equinoctial cut by the horizon is the oblique ascension. Now, set the dial to 12, and turn the globe *westward* until the same star is thereby brought to the western edge of the horizon; the number of degrees from the west *point* to the star is the setting amplitude, and that degree of the equinoctial cut by the horizon is the oblique descension; the number of hours passed over by the dial is the diurnal arc.

319. Find the rising and setting amplitude, the oblique ascension, the oblique descension, and the diurnal arc of Aldebaran at Paris (49° N.)

Rising Amplitude	23½° N.
Oblique Ascension	46° or 3 hrs. 4 min.
Setting Amplitude	23½° N.
Oblique Descension	85° or 5 hrs. 40 min.
Diurnal Arc	14½° hours nearly.

Examples.—Required the rising and setting amplitude, the oblique ascension, the oblique descension, and the diurnal arc of the following stars at the given places:—

α (or Arcturus), at Edinburgh	(56° N.)
α in Gemini, at Madrid	(40½° N.)
α in Ursa Major, at Barbadoes	(13° N.)

320. How do you find the amplitude, the oblique ascension, the oblique descension, and the diurnal arc of the sun, at any given place, on any given day?

Rectify the globe for the given place, and find the sun's place in the ecliptic on the given day. Then proceed with that degree of the ecliptic precisely as with the star in the preceding problem.*

321. Find the sun's amplitude, oblique ascension, oblique descension, and diurnal arc (*i. e.* length of the day) on May the 15th at Lisbon (49° N.)

Sun's place 24th degree of Taurus.
Rising Amplitude 24° N.
Oblique Ascension 35° or 2 hrs. 20 min.
Setting Amplitude 24° N.
Oblique Descension 68° or 4 hrs. 32 min.
Diurnal Arc 14 hours.

EXAMPLES.—Required the sun's amplitude, oblique ascension, oblique descension, and diurnal arc, on the following days at the given places:—

June 1st, at St. Petersburg (60° N.)
November 3d, at Rome (42° N.)
February 5th, at Rio Janeiro (23° S.)

On what point of the compass does the sun rise?

In latitude 48° N. on December 1st.
In latitude 30° S. on May 1st.

* The results thus found, with respect to the sun, though very nearly accurate are not perfectly so, because the sun, whilst above the horizon, continues his progress eastward.

On what point of the compass does the sun set?
In latitude 35° N. on August 12th.
In latitude 27° S. on November 5th.

322. Are there not some days when the sun has no amplitude at any place?

Yes; on March 21st and Sept. 23d, the sun, being in the equinoctial, rises due east, and sets due west (or very nearly so) to all places.

323. Show this by the globe.

324. What is meant by Ascensional Difference, and Descensional Difference?

The difference between the right and oblique ascension; and the difference between the right and oblique descension.

325. How do you find, by the globe, the ascensional or descensional difference of a star, at any given place?

Find its right ascension (Quest. 220), and its oblique ascension or descension (Quest. 318) in degrees: then find their difference, and change it from degrees to time.

326. What is the ascensional difference of Capella in latitude 40° N.?

The right ascension is 75°; the oblique ascension in latitude 40° N. is 15°; the ascensional difference is therefore 60°, or 4 hours.

327. What is the descensional difference of Capella in latitude 40° N.?

The right descension (as ascension) is 75°; the oblique descension in latitude 40° N. is 135°; the descensional difference is therefore 60° also, or 4 hours.

EXAMPLES.—Find the ascensional and descensional difference of Aldebaran in latitude 35° S.

Find the ascensional and descensional difference of Sirius in latitude 35° N.

328. Is not the day always 12 hours long in a right sphere,—*i. e.* to places on the equator?

It is.

329. At what hour does the sun rise and set at such places?

He always rises at 6 and always sets at 6.

330. Does he rise at 6 and set at 6 in an oblique sphere,—*i. e.* to all other places except the poles?

No; during one portion of the year he rises before 6, and sets after 6; during another portion of the year he rises after 6, and sets before 6.

331. During *what* portions of the year does he so rise and set?

When the sun's declination is in the *same* direction as the latitude of the place, he rises before 6 and sets after 6. When the declination and the latitude are in *different* directions, he rises after 6, and sets before 6.

332. How does the sun rise and set on any day between March 21st and September 23d?

Because his declination is then *north*, he rises *before* 6 and sets *after* 6 to places in *north* latitude; and he rises *after* 6 and sets *before* 6 to places in *south* latitude.

333. How does he rise and set on any day between September 23d and March 21st?

Because his declination is then south, he rises

before 6 and sets *after* 6 to places in *south* latitude; and he rises *after* 6 and sets *before* 6 to places in *north* latitude.

334. How does he rise and set on March 21st and September 23d?

He rises at 6 and sets at 6 to all places except the poles.

335. Does not the sun's ascensional difference on any given day show by how much the times of his rising in a right sphere and in an oblique sphere, differ on that day?

It does.

336. Then, if we know the sun's ascensional difference on any given day, at any given place, may we not thence determine the time of his rising at that place?

Yes; for his ascensional difference *in time* shows how much he rises *before* or after 6, according as his declination is in the *same* direction as the latitude, or in a direction *contrary* to it.

337. How can the sun's ascensional difference on any given day be found?

First find his right ascension (Quest. 225); then find his oblique ascension (Quest. 320); their difference, being reduced to time, is the ascensional difference, showing how much *before* or *after* 6 the sun rises at the given place on the given day.

338. Find, in this manner, the time at which the sun rises in latitude 40° N. on May 2d.

The sun's place, on that day, being the 12th degree of Taurus, his declination is north, and in

the same direction as the latitude: therefore he rises before 6. His right ascension (Quest. 225) is 40 degrees; and his oblique ascension (Quest. 320) is 26 degrees: the ascensional difference is, therefore, 14 degrees, or 56 minutes. Consequently, the sun rises 56 minutes before 6, or at 4 minutes past 5.

339. Can you, when you know the time of sunrise, determine therefrom the time of sunset and the length of the day?

Yes; for the time of sunset is as much *after* noon as the time of sunrise is *before* noon. Consequently, when he rises at 4 minutes past 5 (*i. e.* 6 hours and 56 minutes) *before* noon, he sets 6 hours and 56 minutes *after* noon (*i. e.* at 4 minutes before 7); and the length of the day is twice 6 hours and 56 minutes,—*i. e.* 13 hours and 52 minutes.

340. In solving this problem by the globe, is it necessary to take into consideration the declination and the latitude, in order to determine whether the sun rises *before* or *after* 6?

No; it may be seen by the globe; for when the oblique ascension is less than the right ascension, the sun rises *before* 6, and when it is greater, he rises *after* 6.

Examples.—Find the sun's ascensional difference, time of rising, time of setting, and the length of the day, at the following places, on the given days:—

Calcutta ($21\frac{1}{2}$ N.) on June 1st.

R. As. 69°. Oblique As. 60°. Ascen. diff. 9°, or 36 minutes.

Rises 24 minutes past 5. Sets 36 minutes past 6.
Length of the day, 13 hours 12 minutes.
Constantinople (41° N.) on Nov. 10th.
Cape of Good Hope (34½° S.) on May 20th.
Cape Horn (56° S.) on Dec. 30th.

341. What is meant by the azimuth of a heavenly body?

An arc of the horizon contained between its north or south point, and a vertical circle passing through that body.

342. You have already shown how the *meridian* altitude of the sun may be found by the globe,—how do you find his altitude and his azimuth at any given place, for a given *hour* of any given day?

Rectify the globe for the given place, find the sun's place in the ecliptic, and bring it to the brass meridian:—thus the globe is made to represent the actual appearance of the heavens to that place at *noon*, on the given day.

Make the quadrant of altitude represent a vertical circle, by screwing it over the latitude of the place.

Now, if the given time is *before* noon, the sun has not yet attained to the meridian; therefore, the globe must be turned *eastward* as many hours, by the dial, as the given time wants of noon. But, if the given time is past noon, the sun has passed the meridian, and the globe must be turned *westward* as many hours as the given time is past noon.

In this position, the globe represents the exact

appearance of the heavens to the given place, at the given hour of the given day.

Bring the graduated edge of the quadrant to coincide with the sun's place. Then the number of degrees *on* the quadrant shows the altitude at the given hour; and the number of degrees on the horizon, between the graduated edge and the north or south point shows the azimuth at the same hour.

343. What are the sun's altitude and azimuth at St. Petersburg (60° N.) on August 13th, at half-past five in the morning?

Altitude 9°. Azimuth 76° from the N.

EXAMPLES.—Find the sun's altitude and azimuth at the following places on the given days, at the given hours:—

At Lisbon (39 N.) on April 27th, at 3 P.M.

At Rio Janeiro (23° S.) on December 1st, at half-past 7 A.M.

At Barbadoes (13° N.) on June 3d, at half-past 6 A.M.

At London (51½° N.) on the longest day, at 5 P.M.

CHAPTER XI.

Methods of finding the situation of a Ship at Sea.

344. How is the precise situation of a place upon the earth determined?

By its latitude and longitude.

345. When the latitude and longitude of a place are known, is its precise situation on the earth also known?

Yes; for it must be at that point where the known meridian of longitude intersects the known parallel of latitude.

346. How does the captain of a vessel determine the situation of his ship at sea?

By finding in what latitude and longitude the ship is.

347. In what manner can the latitude be found?

It may be computed in various ways from the observed altitudes, amplitudes, and azimuths of heavenly bodies.

348. But how are these altitudes, &c., to be found?

The captain is provided with instruments which enable him to measure the altitude, amplitude, or azimuth of any visible celestial object.

349. Name some of these methods of finding the latitude.

The latitude may be found,—

1st. From the meridian altitude of any celestial object, whose declination is known.

2d. From the amplitude of any celestial object, whose declination is known.

3d. From the altitudes of two stars at the same time.

4th. From observing a known star on the meridian, at the same time that another is in the horizon.

5th. From two observed altitudes of the sun, and the time elapsed between the observations.

350. Can you explain any of these methods of finding the latitude?

To understand the calculations (except in the first case) requires a knowledge of spherical trigonometry; but the methods may be illustrated by the globe. In the first case, however, the calculation is very simple.

351. Explain that calculation then; *i.e.* show how the latitude may be computed from the meridian altitude of any object whose declination is known.

Find the co-altitude by subtracting the altitude from 90°. Call this co-altitude north or south, according as the zenith of the place is north or south of the observed object. Then, if the co-altitude and the declination are of the *same name* (*i.e.* both north, or both south), their *sum* is equal to the latitude, which is of the same *name* as the *greater*. But if the co-altitude and

declination are of *different* names, their *difference* is equal to the latitude, still of the same name as the *greater*.

352. This method supposes the declination of the observed object to be known; but how is that to be found at sea?

By means of the *Nautical Almanac*, in which the sun's declination, previously computed, is given for every day in the year; and the declinations of some of the principal stars are also tabulated.

353. Give an example of this method of finding the latitude.

At sea, the meridian altitude of Sirius in Canis Major was observed to be $43\frac{1}{2}°$ above the *south* point of the horizon (*i.e.* the ship's zenith was to the north of it);—required the latitude of the ship.

90^{d}
$43\frac{1}{2}$ observed altitude.

$46\frac{1}{2}$ co-altitude north.
$16\frac{1}{2}$ south; the dec. of Sirius taken from the *Nautical Almanac*.

Lat. 30° north, because that is the name of the greater quantity.

354. How may this method be illustrated by the globe?

Bring the celestial object to the brass meridian; then count the degrees of altitude from that object along the brass meridian, towards the north or south point of the horizon (whichever

is required); mark where the reckoning ends; bring this mark to correspond with the north or south point of the horizon (whichever is required); and the elevation of the pole will then show the latitude.

355. Solve the preceding problem by the globe.

356. Do you illustrate the method in the same way when the observed object is the sun?

Yes; the sun's place in the ecliptic, on the given day, must be brought to the meridian, and the reckoning commenced from that.

357. Suppose the observed celestial object to be a circum-polar star, and that its altitude is taken as it crosses the meridian *below* the elevated pole:—will the same apply?

No; in that case, the latitude is always equal to the sum of the altitude and co-declination, and always of the *same name* as the elevated pole.

358. Give an example.

At sea the meridian altitude of Capella, taken below the north pole, was $4\frac{1}{2}°$;—required the latitude of the ship.

$90°$
$45\frac{1}{2}$ dec. of Capella (from *Naut. Alm.*)

$44\frac{1}{2}$ co-declination.
$4\frac{1}{2}$ observed altitude.

Lat. $49°$ north.

359. How is this case to be illustrated by the globe?

Bring the star to the brass meridian *below* the pole; count the degrees of altitude from it towards the horizon, and mark where the reckoning ends; bring this mark to coincide with the horizon, and the elevation of the pole will then show the latitude.

360. Solve the preceding problem by the globe.

EXAMPLES.—Find, by calculation, the latitudes in which the following observations were made (the declinations being given), and show that the same results are obtained by using the globe.

1st.—*Betelgeuse in Orion* (dec. 7½° N.),—observed meridian altitude 46° above the *south* point of the horizon—*i.e.* the ship's zenith to the *north* of it. Required lat. 51½° N.

2d.—*Dubbe in Ursa Major* (dec. 63° N.),—observed meridian altitude 57° above the *north* point of the horizon—*i.e.* the ship's zenith to the *south* of it.

3d.—*Capella in Auriga* (dec. 45½° N.),—observed meridian altitude taken *below* the north pole, 15½°.

4th.—*Acherner in Eridanus* (dec. 58° S.),—observed meridian altitude taken *below* the south pole, 28°.

Find, by calculation, the latitudes in which the following observations of the sun's meridian altitude were made, and show that the same results are obtained by using the globe.

May 9th.—Mer. alt. above S. point of the horizon 58°; Lat. 49° N.

June 7th.—Mer. alt. above N. point of the horizon $44\frac{1}{2}°$.

Sept. 2d.—Mer. alt. above S. point of the horizon 38°.

Nov. 6th.—Mer. alt. above N. point of the horizon $70\frac{1}{2}°$.

Dec. 30th.—Mer. alt. above S. point of the horizon 54°.

361. Illustrate, by the globe, the second method of finding the latitude—*i.e.* from the amplitude of a celestial object.

Bring the object, or (if it be the sun) its place in the ecliptic on the given day, to the eastern or western edge of the horizon, according as it is the rising or the setting amplitude which is known. Then elevate or depress the pole until the object (or its place) coincides with the known degree of amplitude on the horizon. Then, the elevation of the pole will show the latitude.

EXAMPLES.—1st. In north latitude, the rising amplitude of Aldebaran was observed to be $28\frac{1}{2}°$ N.—in what latitude was the ship?

2d. In south latitude, on May 26th, the sun's rising amplitude was observed to be 26° N.—in what latitude was the ship?

3d. In north latitude, on Jan. 1st, the sun's setting amplitude was observed to be 37° S.—in what latitude was the ship?

4th. In south latitude, on Aug. 5th, the sun's setting amplitude was observed to be 19° N.—in what latitude was the ship?

5th. In south latitude, the rising amplitude of

Rigel, in Orion, was observed to be 10° S.—in what latitude was the ship?

6th. In north latitude, on June 21st, the sun's rising amplitude was observed to be 44° N.—in what latitude was the ship?

362. How do you illustrate, by the globe, the third method of finding the latitude—*i.e.* from the observed altitudes of two stars at the same time?

Find the co-altitude of each star. Take from the equinoctial, with a pair of compasses, a number of degrees equal to the co-altitude of one star, and, with that star as a centre, describe an arc on the globe. In a similar manner take the co-altitude of the other star in the compasses, and, from that star describe another arc. These arcs will intersect each other in the zenith, which being brought to the brass meridian shows the latitude.

Examples.—1st. In north latitude, the altitude of Arcturus was observed to be 59°, when that of Cor Leonis was 45°—what was the latitude?

Forty-five degrees north.

2d. In north latitude, the altitude of *α* in Andromeda was observed to be 28°, when that of *α* in Cygnus was 65°—what was the latitude?

3d. In south latitude, the altitude of Cor Scorpionis was observed to be 44°, when that of Spica Virginis was 61°—what was the latitude?

3d. In south latitude, the altitude of Sirius was observed to be 55°, when that of Bellatrix was 63°—what was the latitude?

363. How do you illustrate, by the globe, the fourth method of finding the latitude—*i.e.* by observing a star on the meridian at the same time that another is in the horizon?

Bring the star that was observed to be on the meridian to the brass meridian; prevent the globe from turning on its axis, and elevate or depress the pole until the other star coincides with the horizon. The elevation of the pole then shows the latitude.

EXAMPLES.—1st. Altair (in Aquila) was observed to be on the meridian when Arcturus (in Böotes) was setting—what was the latitude?

Fourteen degrees south.

2d. α (in Andromeda) was observed to be on the meridian, when α (in Gemini) was rising—what was the latitude?

3d. Fomalhaut (in Piscis Australis) was observed to be on the meridian when Aldebaran was rising—what was the latitude?

4th. α (in Perseus) was observed to be on the meridian when α (in Serpentarius) was setting—what was the latitude?

364. How do you illustrate, by the globe, the fifth method of finding the latitude—*i.e.* from two observed altitudes of the sun, and the time elapsed between them?

Find the sun's declination on the given day; take from the equinoctial, with a pair of compasses, a number of degrees equal to that declinaton; apply the compasses to a meridian, or one of the colures, and mark the point to which they extend from the equinoctial, northward or southward,

to the declination. Change the elapsed time into degrees (by reducing it to minutes, and dividing by 4); count those degrees westward along the equinoctial from the meridian or colure, and mark where the reckoning ends; bring that point of the equinoctial to the brass meridian, and again mark off the declination as before, but along the edge of the brass meridian.

Take, from the equinoctial, with your compasses, the complement of the first observed altitude; and, with the first marked point of declination as a centre, describe an arc on the globe. Then take the complement of the second observed altitude; and, with the second marked point of declination as a centre, describe a second arc.

These two arcs will intersect each other in the zenith, which, being brought to the brass meridian, will show the latitude.

EXAMPLES.—In north latitude, on that day of the year when the sun's declination was $19\frac{1}{2}°$ N., two observations were made of his altitude in the morning, the latter being made one hour and a half after the former. The first observed altitude was $38\frac{1}{4}°$; the second was $51\frac{1}{2}°$,—in what *degree* of north latitude were these observations made?

Answer. The time in degrees is $22\frac{1}{2}°$
The comp. of the 1st altitude is $51\frac{3}{4}°$
The comp. of the 2d altitude is $39\frac{1}{2}°$
The required latitude is about $51°$ N.

2d. In north latitude, when the sun's declination was $22\frac{3}{4}°$ north, two observations were made

of his altitude: one at 10 hrs. 54 min. A.M., the other at 1 hr. 17 min. P.M.; at the former time, his altitude was $53\frac{1}{2}°$; at the latter, it was $52\frac{3}{4}°$—what was the latitude of the observer?

3d. In north latitude, when the sun's declination was $22\frac{1}{2}°$ south, two observations were made of his altitude in the afternoon, at the interval of 1 hour and 20 minutes; the first altitude was $14\frac{1}{4}°$, and the second was $8\frac{1}{2}°$—what was the latitude?

365. You have now illustrated several methods by which the latitude may be found; but, before the precise situation of a ship can be determined, the longitude must also be known—how is this to be found?

The longitude of a ship at sea is found by comparing the time at the ship with the time at the first meridian, ascertaining their difference, and changing that difference into degrees.

366. This supposes the time at the ship to be known; but how can that be found?

When the latitude is known, the *apparent* time may be computed from the observed altitude of any celestial object whose declination is known; and this apparent time may (if necessary) be reduced to *mean* time, by applying to it the equation of time taken from the *Nautical Almanac.*

367. How can the time at the first meridian be found?

The best method (for certain correctness) is by observations made on the distances of the moon from other celestial objects. This method

is called, "The Problem of Lunar Distances." It involves some abstruse calculations, and, therefore, the accuracy of the chronometer is generally, and with safety, depended on.

368. What is a chronometer?

A time-piece so skilfully constructed as always to show accurately (or *very* nearly so) the mean time at the first meridian.

369. When the captain of a ship has found the mean time at the ship by a corrected celestial observation, and the mean time at the first meridian by his chronometer—how is he thence to deduce the ship's longitude?

The difference of time must be changed into degrees (by reducing it to minutes, and dividing by 4); the number of degrees thus found shows the ship's distance east or west of the first meridian—*i.e.* its longitude.

370. Why must minutes of time be divided by 4 to reduce them to degrees?

Because the earth revolves upon its axis at the rate of one degree in 4 minutes; and, therefore, the heavens appear to revolve at the *same rate.*

371. When he has found this difference of time, and reduced it to degrees, how does he know whether the ship is so many degrees to the *east* or to the *west* of the first meridian?

When the time at the ship is *later* than that at the first meridian, the ship is in *east* longitude. When the time at the ship is *earlier* than that

at the first meridian, the ship is in *west* longitude.

372. How is that fact known?

The earth revolves from west to east, and the heavens therefore appear to revolve from east to west: consequently, the sun comes *first* to the more easterly of any two meridians, and makes noon there before it is noon to the more westerly. Therefore the more easterly of any two meridians always has the *later* hour of the day; and consequently when the time at the ship is *later* than that at the first meridian, the ship is to the *east* of the first meridian; but when the time at the ship is *earlier* than that at the first meridian, the ship is to the *west* of the first meridian.

373. Suppose the mean time at a ship (as found by a celestial observation) to be 7 hrs. 3 m. P.M., and that at the first meridian (as found by chronometer) to be 3 hrs. 30 m. P.M., in what longitude is the ship?

The diff. of time is 3 hrs. 33 m.
60

4)213 in minutes.

Longitude $53\frac{1}{4}°$ { *east*, because the ship's time is the later.

374. Suppose the mean time at a ship to be 5 hrs. 11 m. A.M., and that at the first meridian to be 11 hrs. 33 m. A.M., in what longitude is the ship?

The diff. of time is 6 h. 22 m.

60

4)382 in minutes.

Longitude $95\frac{1}{2}°$ { *west*, because the ship's time is the earlier.

375. Suppose the mean time at a ship to be 10 h. 13 m. A.M., and that at the first meridian to be 2 h. 47 m. P.M., in what longitude is the ship?

The diff. of time is 4 h. 14 m.

60

4)254 in minutes.

Longitude $63\frac{1}{2}°$ { *west*, because the ship's time is the earlier.

376. Suppose the mean time at a ship to be 3 h. 2 m. A.M., and the time at the first meridian to be 10 h. 5 m. P.M. of the preceding day, in what longitude is the ship?

The diff. of time is 4 h. 57 m.

60

4)297 in minutes.

Longitude $74\frac{1}{4}°$ *east*, because the time at the ship (*being on the following day*) is the later.

377. Suppose the time at a ship to be 9 h. 37 m. P.M. of Nov. 1st, and the time by chronometer to be 2 h. 49 m. of Nov. 2d, in what longitude is the ship?

The diff. of time is 5h. 12m.
60

4)312

Longitude 78 *west*, because the time at the ship (*being on the preceding day*) is the earlier.

Examples.—Find the longitude from the following mean times:—

		Hrs.	Min.		
1.	Ship's time by observation	11	4	P.M.	
	Greenwich time by chron.	3	48	P.M.	
2.	Ship's time by observation	9	34	A.M.	
	Greenwich time by chron.	2	51	P.M.	
3.	Ship's time by observation	4	5	P.M.	
	Greenwich time by chron.	11	4	A.M.	
4.	Ship's time by observation	3	12	A.M.	Aug. 2.
	Greenwich time by chron.	10	11	P.M.	Aug. 1.
5.	Ship's time by observation	11	10	P.M.	Jan. 1.
	Greenwich time by chron.	4	2	A.M.	Jan. 2.

378. You said that when the latitude is known, the apparent time may be computed from the observed altitude of any celestial object whose declination is known. Can you explain the process of computation?

It cannot be understood without a knowledge of Spherical Trigonometry.

379. Can the method be illustrated by the globe?

Yes.

380. Suppose the body whose altitude is observed to be the sun, and let the latitude be known, how can you find by the globe the apparent time of the observation?

Rectify the globe, and screw the quadrant of altitude over the latitude; bring the sun's place to the brass meridian, and set the dial to 12. Turn the globe eastward or westward, according as the time of observation was before or after noon, until the sun's place coincides with the observed altitude on the quadrant; then the number of hours passed over by the dial will show the time, before or after noon, at which the observation was made.

Examples.—In latitude 39 N., on June 3d, by an observation made before noon, the sun's altitude was 39°. At what time was the observation made?

Three hours and three-quarters before noon; *i. e.* at ¼ past 8 in the morning.

In latitude 27 S., on Dec. 1st, by an observation made after noon, the sun's altitude was 42°. At what time was the observation made?

In latitude 44 S., on Dec. 21st, by an observation made after noon, the sun's altitude was 9°. At what time was the observation made?

In latitude 58 N. on June 21st, by an observation made before noon, the sun's altitude was 17°. At what time was the observation made?

381. Suppose the body whose altitude is observed to be a star, and let the latitude be known, how can you find by the globe the time at which the observation was made?

Rectify the globe, screw the quadrant over the latitude, bring the sun's place to the brass meridian, and set the dial at 12. Turn the globe *westward* until the star coincides with the given altitude on the quadrant, on *that side* of the meridian on which the star was situated when observed: the hours passed over by the dial will show the time *after* noon.

Examples.—On December 21st, in latitude 51½° N., when Sirius was west of the meridian, his altitude was observed to be 8°. At what time was the observation made?

Sixteen hours after noon, *i. e.* four in the morning.

On December 21st, in latitude 32° N., when *α* in Serpentarius was west of the meridian, its altitude was observed to be 18°. At what time was the observation made?

On June 21st, in latitude 47° S., when Arcturus was east of the meridian, his altitude was observed to be 15°. At what time was the observation made?

On June 21st, in latitude 23° S., when Aldebaran was to the east of the meridian, his altitude was observed to be 15°. At what time was the observation made?

382. To obtain the mean time from the apparent time (thus found by observation), must the equation of time (Quest. 198) be added or subtracted?

At those periods of the year when the mean time is *before* the apparent time, the equation must be added to the apparent time. But, when the

mean time is behind the apparent time, the equation must be subtracted from the apparent time. It is always stated in the Nautical Almanac whether the equation is to be added or subtracted.

Additional Examples in finding the Longitude.

(Required the Ship's Longitude.)

	Hrs.	Min.
Ship's apparent time by Obs.	9	17 P. M.
Equation to be subtracted .		14
Ship's mean time . .	9	3 P. M.
Mean time by Chronometer .	2	54 P. M.
Ship's apparent time by Obs.	3	13 A. M.
Equation to be added . . .		11
Mean time by Chronometer .	11	3 A. M.
Ship's apparent time by Obs.	3	47 P. M.
Equation to be added . . .		15
Mean time by Chronometer .	9	5 A. M.
Ship's apparent time by Obs.	5	23 A. M.
Equation to be subtracted .		9
Mean time by Chronometer .	1	44 P. M.
Ship's apparent time by Obs.	3	19 P. M.
Equation to be subtracted .		10
Mean time by Chronometer .	10	4 P. M.

CHAPTER XII.

Methods of finding the Variation of the Compass at Sea.

383. You have stated that the magnetic needle does not, at all times and places, point *due* north, but is subject to a variation, pointing sometimes to the east and sometimes to the west of the true north point of the horizon. Is it not necessary at sea to know the amount and direction of this variation?

It is; for otherwise the ship could not be steered with certainty to its place of destination.

384. By what means is this variation found at sea?

By comparing the amplitude or azimuth of a heavenly body (usually the sun), as observed by compass, with the true amplitude or azimuth, as found by calculation.

385. What is the amplitude or azimuth of a heavenly body, by compass, called?

The magnetic amplitude or azimuth.

386. Can you explain the process of calculation required to find the true amplitude or azimuth?

It cannot be understood without a knowledge of Spherical Trigonometry.

387. Can the amplitude and azimuth be found by the globe?

Yes; the method has been already explained, in answer to Quest. 320 and Quest 342.

388. Are the amplitude and azimuth, as found by the globe, the true amplitude and azimuth?

Very nearly so.

389. Find (Quest. 320) the sun's rising amplitude, on May 13th, in latitude 37° N.

About 23½° to the north of the east.

390. Suppose the observed magnetic amplitude to be, at the same time, 35° to the north of the east—what is the variation?

11½° east.

391. How do you know that the variation is east?

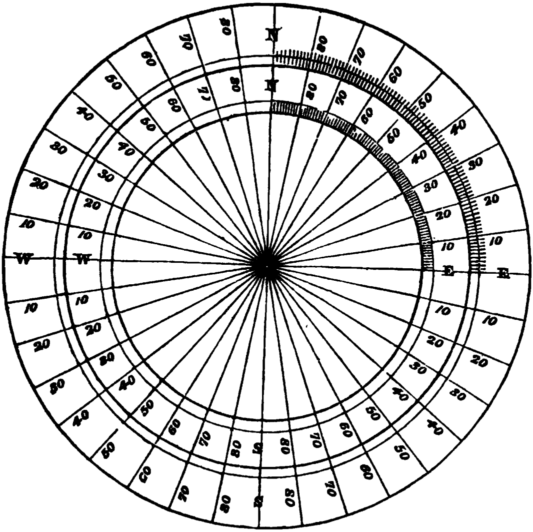
The sun's distance to the north of the magnetic east is *greater* than his distance to the north of the true east; consequently the magnetic east is to the *south* of the true east; and therefore the magnetic north is to the *east* of the true north. (Let the pupil examine the wooden horizon in illustration of this).*

* Most young pupils find considerable difficulty in determining the *direction* of the variation. The author has always found the following simple mode of illustration remove the difficulty. Let two circular pieces of card-board, one larger than the other, be divided as in the opposite figure. The larger of these should be fastened to a piece of board, and the smaller made moveable on its centre by a pin; then the larger circle represents the horizon, on which the *true* amplitude or azimuth

392. Suppose the observed magnetic amplitude to be, at the same time, $15\frac{1}{4}°$ towards the east, what is then the variation?

Eight degrees and a quarter west.

may be marked; and the smaller circle represents the compass, on which the magnetic amplitude or azimuth may be marked. Thus, in illustration of the preceding example, let the 35th degree north of the east on the



inner circle be made to coincide with 23½ on the outer circle; and it will then be seen that the N. point of the inner circle (*i. e.* the compass) is to the east of the N. point on the outer circle (*i. e* the horizon).

393. How do you know that the variation is *west?*

The sun's distance to the north of the magnetic east is *less* than his distance to the north of the true east; consequently the magnetic east is to the *north* of the true east, and therefore the magnetic north to the west of the true north.

394. Find the sun's rising amplitude in lat. 41° N. on Nov. 14th?

About 25½° to the south of the east.

395. Suppose the observed magnetic amplitude to be, at the same time, 37° to the south of the east; what is the variation?

Eleven degrees and a half west.

396. How do you know that the variation is *west?*

Because the sun's distance to the south of the magnetic east is *greater* than his distance to the south of the true east; the magnetic east is to the *north* of the true east; and therefore the magnetic north to the *west* of the true north.

397. Suppose the observed magnetic amplitude to be 16½° to the south of the east; what is then the variation?

Nine degrees east.

398. How do you know that the variation is *east?*

Because the sun's distance to the south of the magnetic east is *less* than his distance to the south of the true east; the magnetic east is to the south of the true east; and therefore the magnetic north to the *east* of the true north.

EXAMPLES.—What was the variation of the compass—

In lat. 47° N., on June 3d, if the observed magnetic amplitude of the sun, when rising, was $25\frac{1}{2}$° to the north of the east?

In lat. 33° S., on Jan. 5th, if the sun's magnetic amplitude, when setting, was 31° to the south of the west?

In lat. 67°. S., on Feb. 11th, if the sun rose, by compass, E. S. E.?

In lat. 51°. N., on Aug. 12th, supposing that the sun set, by compass, N. W by W.?

399. Find (Quest. 342) the sun's azimuth in lat. 57° N. on Sept. 3d, at 9 o'clock in the morning.

About 54 to the east of the south.

400. If the observed magnetic azimuth, at the same time, is 72° east of the south; what is the variation?

Eighteen degrees east.

401. How do you know that the variation is *east*?

Because the sun's distance to the east of the magnetic south is *greater* than his distance to the east of the true south; the magnetic south is to the *west* of the true south; and therefore the magnetic north to the *east* of the true north.

402. Suppose the observed magnetic azimuth to be 36° to the east of the south, what then is the variation?

Eighteen degrees west.

403. How do you know that the variation is *west?*

Because the sun's distance to the east of the magnetic south is *less* than his distance to the east of the true south; the magnetic south is to the *east* of the true south; and therefore the magnetic north to the *west* of the true north.

404. Find the sun's azimuth in the same latitude on June 1st, at 5 in the morning.

About 65° to the east of the north.

405. Suppose the observed magnetic azimuth to be, at the same time, 74° to the east of the north; what is the variation?

Nine degrees west.

406. How do you know that the variation is *west?*

Because the sun's distance to the east of the magnetic north is *greater* than his distance to the east of the true north, the magnetic north must be to the *west* of the true north.

407. Suppose the observed magnetic azimuth to be 56° to the east of the north; what then is the variation?

Nine degrees east.

408. How do you know that the variation is *east?*

Because the sun's distance to the east of the magnetic north is *less* than his distance to the east of the true north, the magnetic north must be to the *east* of the true north.

EXAMPLES.

In lat. 39° N., if the observed magnetic azimuth of the sun, on Aug. 25th, at half-past 8 in the morning, is 82½ to the east of the south; what is the variation?

Suppose the sun's observed magnetic azimuth, in lat. 43° N., on July 28th, at 5 o'clock in the afternoon, to be 74° to the west of the north; what is the variation?

Suppose the observed magnetic azimuth of the sun, in lat. 32° S., on May the 9th, at half-past 10 in the morning, to be 41° to the east of the north; what is the variation?

Suppose the observed magnetic azimuth of the sun, in lat. 60° S., on Dec. 2d, at half-past 6 in the evening, to be 59° to the west of the south; what is the variation?

LONDON
R. CLAY, PRINTER, BREAD-STREET-HILL